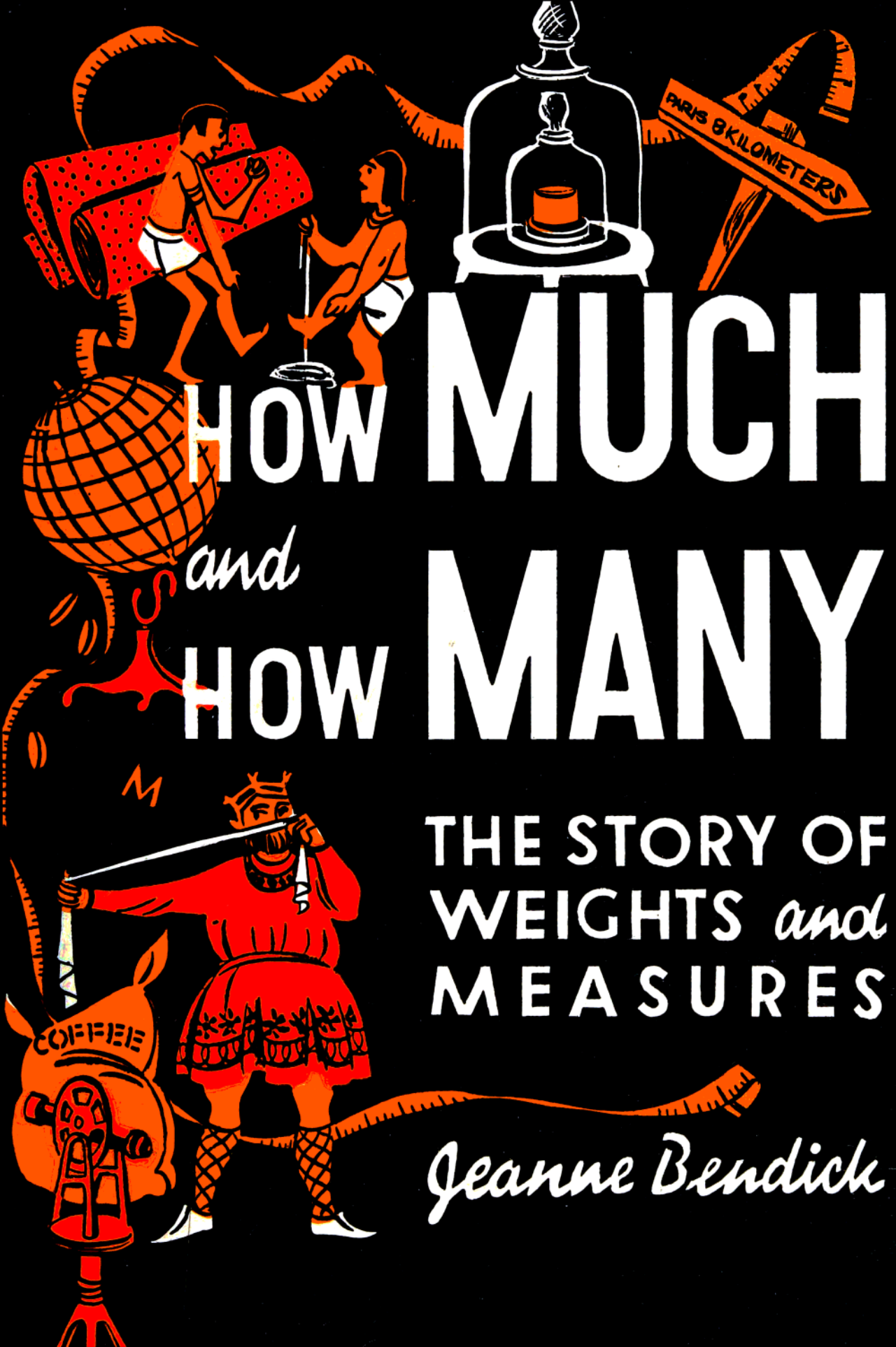

HOW MUCH and HOW MANY

THE STORY OF WEIGHTS and MEASURES

Jeanne Bendick

JEANNE BENDICK has both written and illustrated a great number of books for young people, including many in the science field.

With her clear, concise writing, and her illustrative – and amusing – drawings, she is able to make even the most difficult subject appear simple and exciting.

In addition to *How Much and How Many*, updated 1960, she is author as well as illustrator of *Electronics for Young People*, New Fourth Edition; *All Around You;* with her children, *Have a Happy Measle;* with Robert Bendick, *Television Works Like This*, Fourth Edition, Revised and Enlarged; with Marcia Levin, *Take a Number, Take Shapes, Lines and Letters*, and *Pushups and Pinups;* with Leonard Simon, *The Day the Numbers Disappeared;* and with Marcia Levin and Leonard Simon, *Mathematics Illustrated Dictionary*.

Mrs. Bendick lives in Rye, New York, with her husband and two children.

How Much and How Many

THE STORY OF WEIGHTS AND MEASURES

Text and pictures by JEANNE BENDICK

Just as man once learned to measure land or to weigh things, he must now learn to measure space. In this updated printing of her successful and well-established book, Jeanne Bendick has added valuable new material that explains measurements used in rocketry, atomic science and space exploration.

In addition, here are all the original facts on weights and measures – not only what they are, but how they got that way and why.

Do you know how a yard got to be a yard?

What was the first weight?

How did men first measure time?

How do you draw a map to scale?

How do you measure the force of gravity?

We live in a world where everything is weighed, measured or counted in some way. This book tells the story of these ways, from a grain to a barge, from a micron to a light year. A fascinating book for people of all ages – a valuable reference book for every library.

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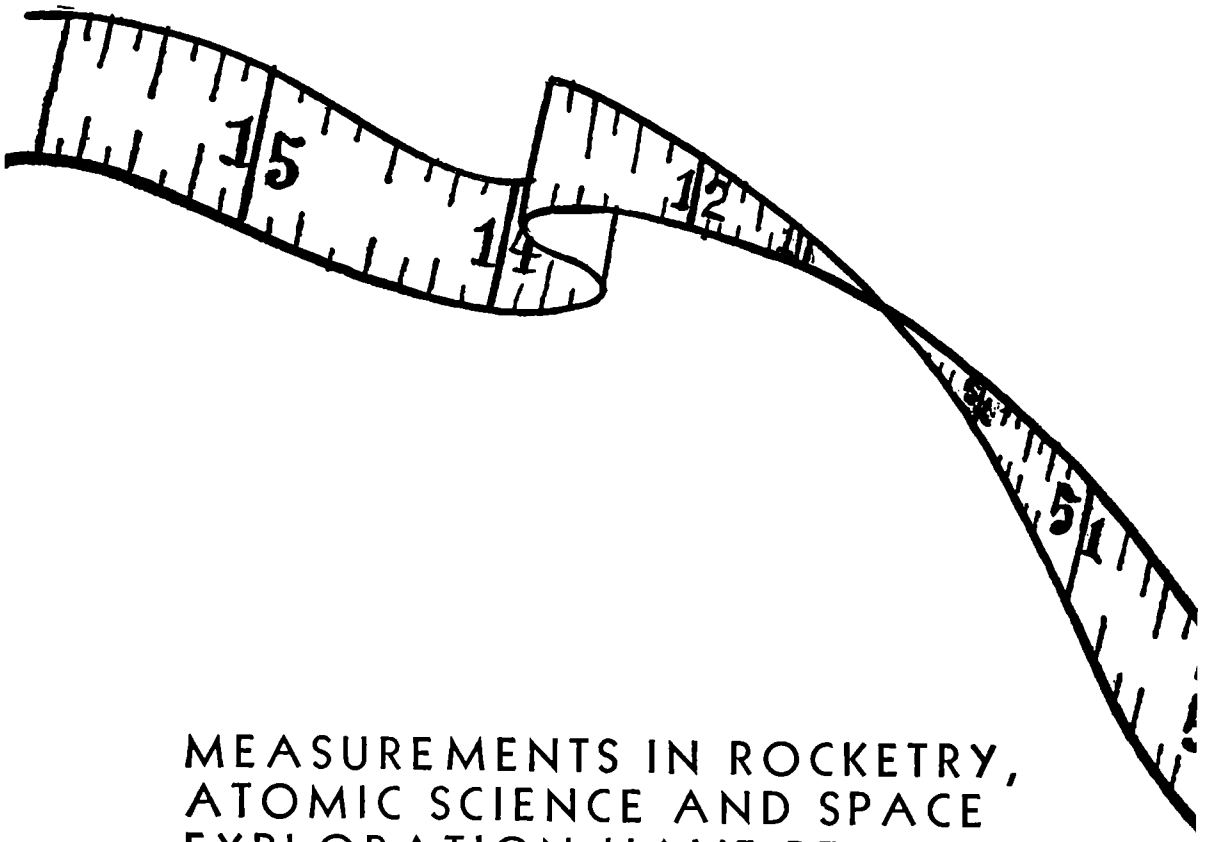


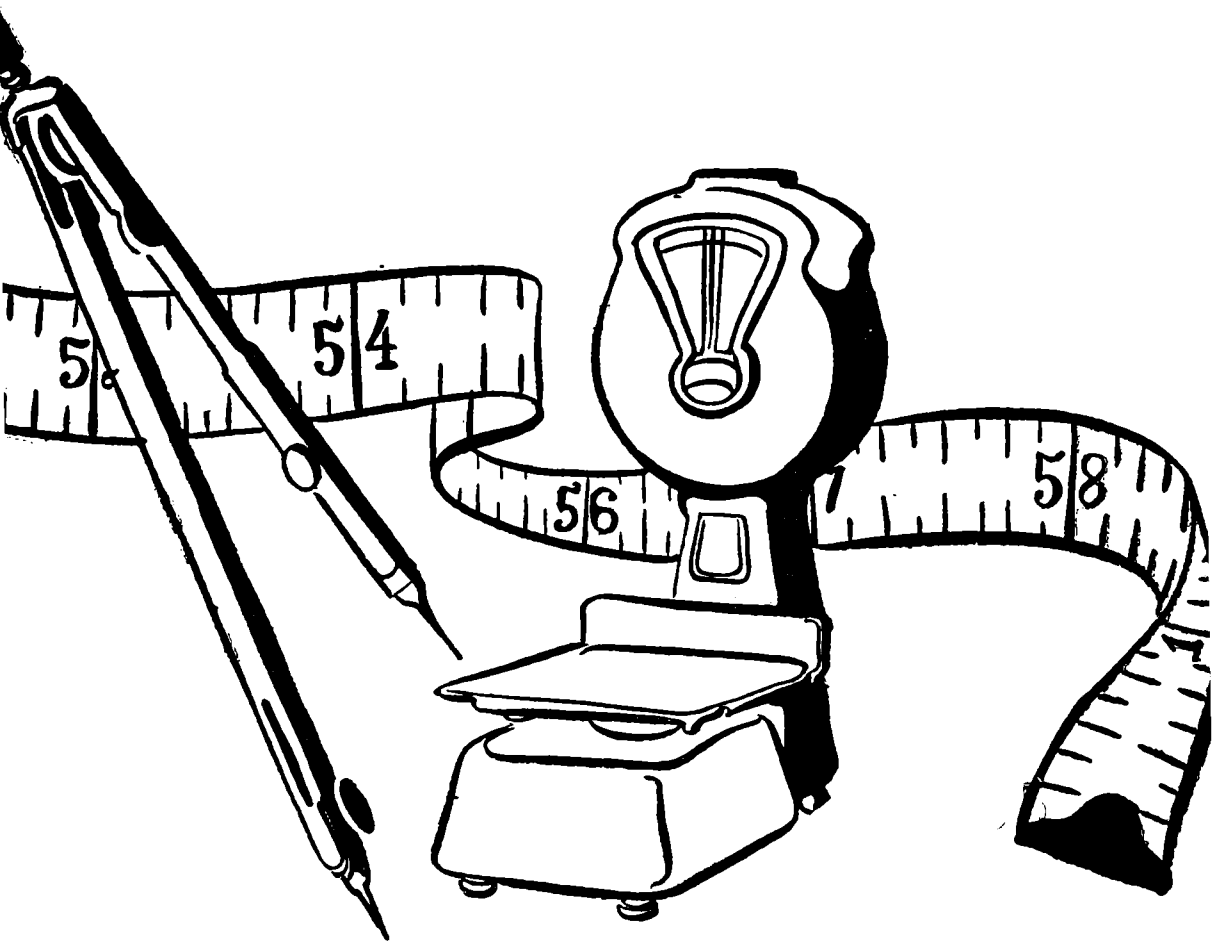
MEASUREMENTS IN ROCKETRY, ATOMIC SCIENCE AND SPACE EXPLORATION HAVE BEEN ADDED TO THIS PRINTING

McGRAW-HILL BOOK COMPANY
NEW YORK TORONTO LONDON

HOW MUCH
AND
HOW MANY

THE STORY OF WEIGHTS AND MEASURES

by Jeanne Bendick



Author's Note

This book has been brought up to date and includes measurements used in rocketry, atomic science and space exploration.

JEANNE BENDICK

HOW MUCH AND HOW MANY

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TWENTY-FOURTH PRINTING

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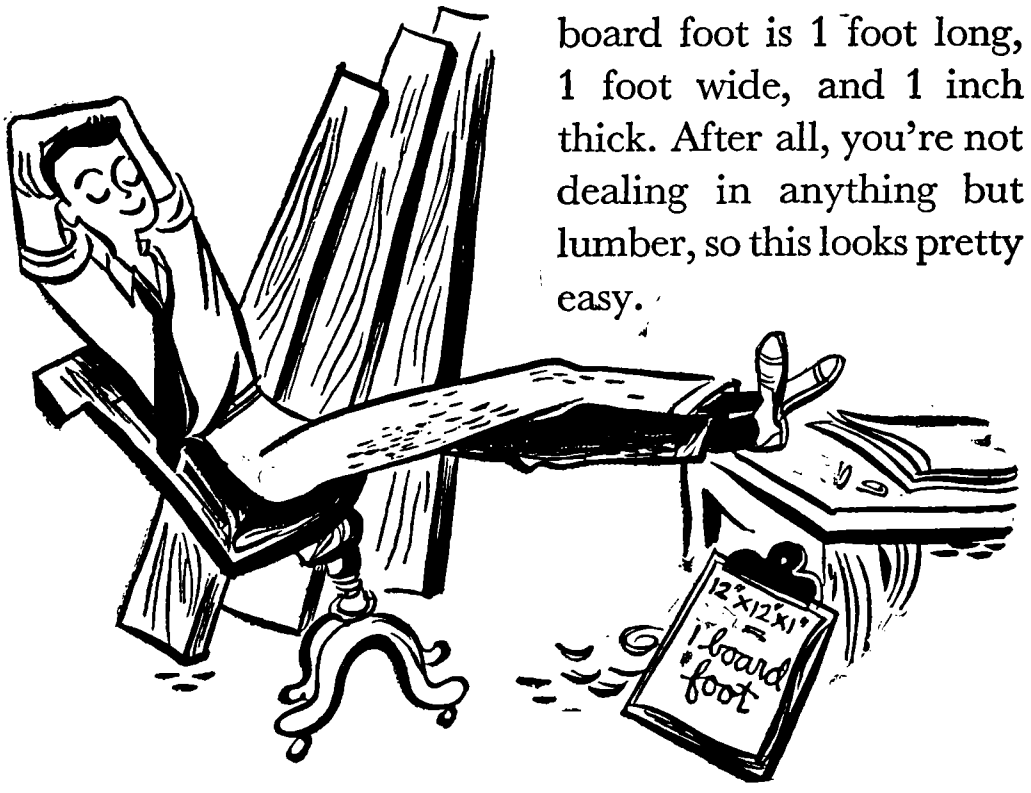
HOW MUCH AND HOW MANY

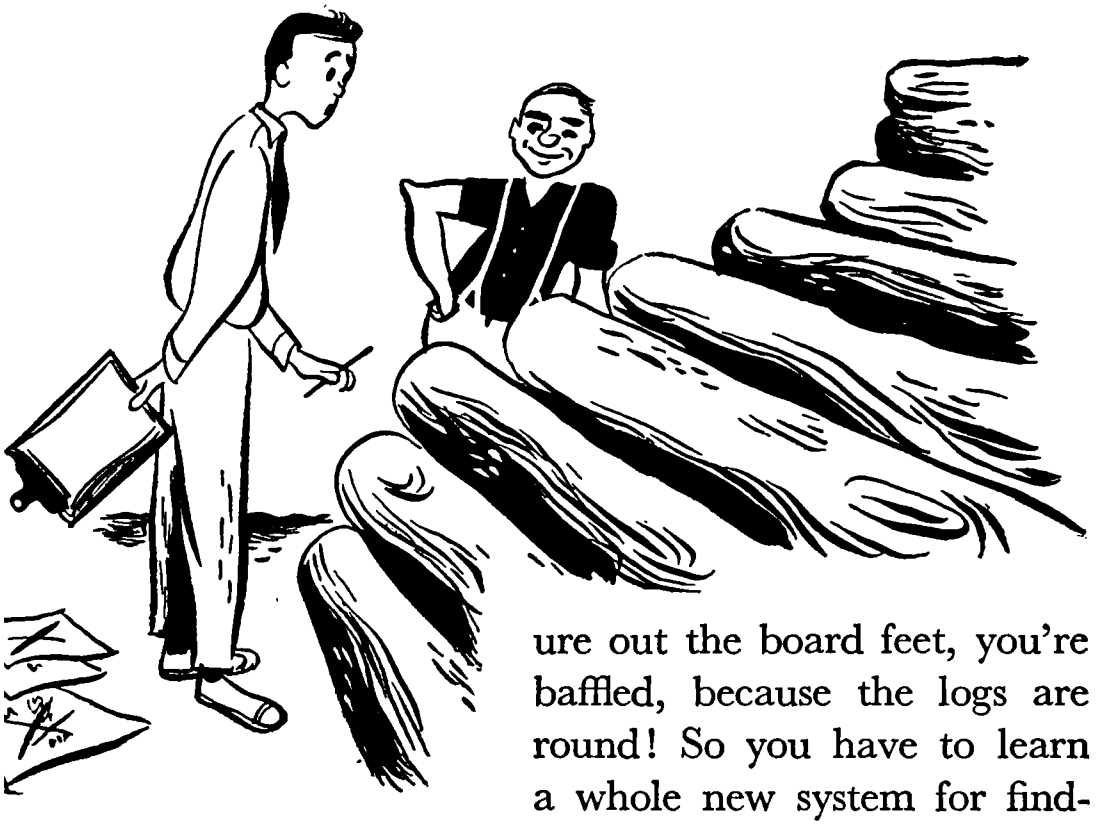
EVERYTHING you eat and wear and buy, the streets and land around you, the house you live in, the rain, wind, and snow, the sea, the stars, and the days, have been measured or weighed or counted in some way.

The ways of measuring and counting this variety of things are almost endless. Sometimes a single thing can be measured or weighed in a dozen different ways.

Suppose you worked in a lumberyard at a seaport. You know that lumber is measured in board feet. A board foot is 1 foot long, 1 foot wide, and 1 inch thick. After all, you're not dealing in anything but lumber, so this looks pretty easy.



Well, one day you have to buy some hickory logs from a logger in South Carolina. But when you start to figure out the board feet, you're baffled, because the logs are round! So you have to learn a whole new system for finding the number of board feet in a shipment of round logs.

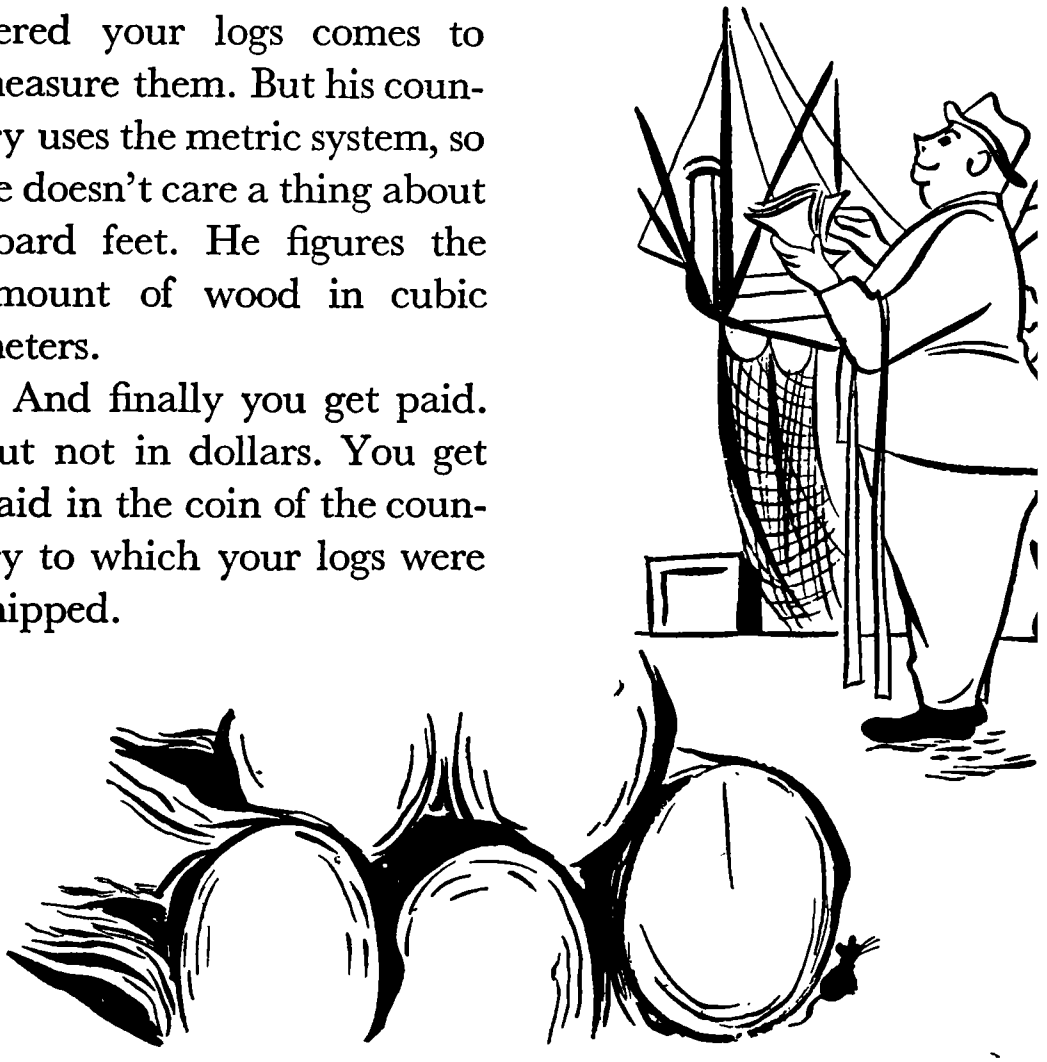


Then you arrange to have the logs brought to your port by rail, and you discover that now logs aren't figured in board feet at all, but by the hundredweight. You pay freight for them at so much for every hundred pounds. And then, because you are going to ship these logs abroad, you have to pay ocean freight—but you pay that by the ton.

Now suppose logs have landed at Le Havre (le-AVR), in France. You have to pay dock rent. By weight or board feet? Not at all. By the area of space that the logs take up on the wharf.

The Frenchman who ordered your logs comes to measure them. But his country uses the metric system, so he doesn't care a thing about board feet. He figures the amount of wood in cubic meters.

And finally you get paid. But not in dollars. You get paid in the coin of the country to which your logs were shipped.



These logs are still just logs. Before they can be made into a house or a ship, they will have been weighed or measured in half a dozen different ways. The same thing has happened to almost everything around you.

Our civilization and our ways of doing business are quite complicated now, but even from the earliest times people had to find ways of measuring things. A man wanted to know how much land he cultivated, how many arrows he could exchange for grain to eat, or how much cloth his wife needed for her new dress.

At first his ways of measuring these things were very simple. He used the most convenient measure—himself. He took the length of his foot or his stride, the span of his hand or the thickness of his finger. Sometimes he used another kind of measure—a stick, a grain of wheat, or the amount of land his oxen could plow in one day. Sometimes he just traded a handful of arrows for a handful of something he needed more.

But as civilization grew more complicated, it was very confusing to measure in these ways. How could a foot be used as a measure when one man's foot was so much

longer than another's? Or his hand larger or his fingers thicker? As soon as men began doing business on a large scale, they needed better ways of measuring. As soon as they began building towns and ships, dividing land, trading with men they never saw, the early, natural ways of

measuring weren't good enough. There had to be standard measures that were the same everywhere.

It was important to the trader between Babylon (BABB-i-lon) and Jerusalem to know that an ell of cloth in one city was about equal to an ell of cloth in the other. And if a king wanted his palace walls built 50 cubits high, he didn't expect each workman to measure off those cubits in the old way—from the tip of his elbow to the end of his middle finger. He wanted the walls measured

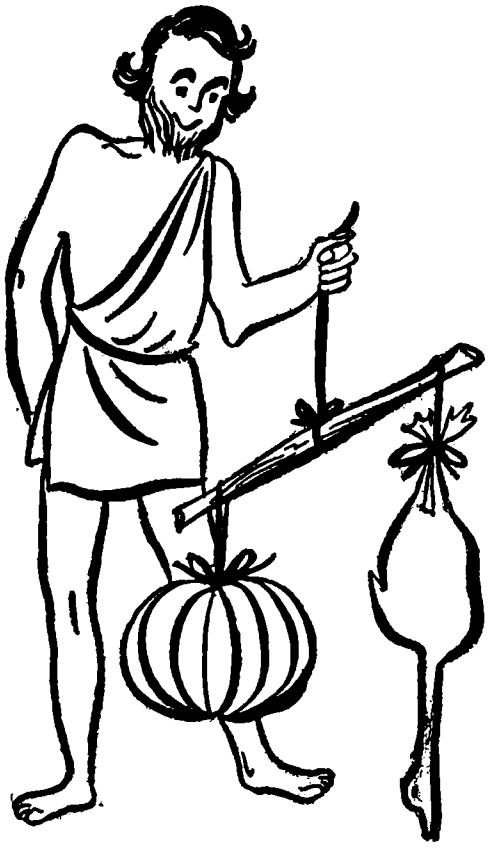
with measuring rods, so that they would be the same height all around.

Measuring came before weighing. It is a simple thing to measure an amount of something—the fullness of a certain gourd or an eggshell, the length of a foot or an arm. Weight, as a separate way of measuring, is harder to figure out.

The first way of thinking about weight was probably the amount a man could carry. He knew that it often had nothing to do with actual size because, while it was easy to carry a bundle of straw larger than himself, he could carry only a couple of rocks or a fairly small piece of iron. And while a bucket of berries was light, the same bucket filled with sand was really quite heavy.

So the first way of counting weight was what a man could hold or carry. Actually he wasn't measuring weight at all, but size and number. He didn't know how much rocks weighed, only that two were all he could manage.

The fact that weight itself was a way of measuring quite separate from size or material was an idea that took more time to develop. At first people compared weight by balancing small objects, one in each hand, and guessing whether one was heavier or whether the two weighed about the same. It was a long time before someone



thought of a weighing machine—a stick hanging by a cord tied around its middle. The objects that were being weighed were hung on other cords, one at each end of the stick. If they balanced, the stick stayed parallel to the ground. If one was heavier, the stick dipped on that side.

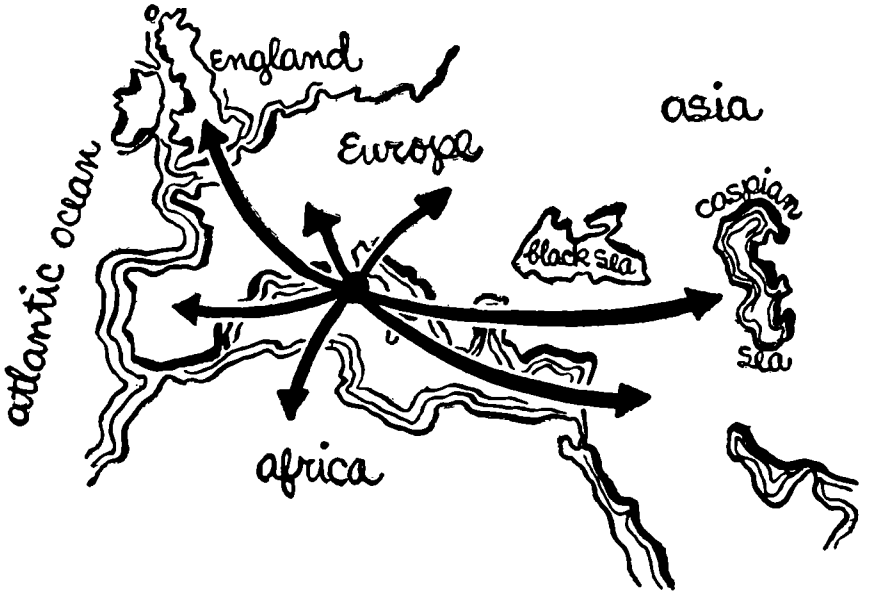
By about 3000 B.C. the Egyptians were making various kinds of small weights out of stone. This was a tremendous step forward in thinking. These weights in themselves were nothing that anybody wanted. They were used to represent amounts of something else that did have value.

The ancient Babylonians, the Egyptians, the Greeks, and the Romans standardized many hundreds of different weights and measures to meet the needs of their busy civilizations. This means that the same weights were used by everybody. They had common weights for honey and other foods, for

drugs, metals, and precious stones. They had measures for the things they built, for cloth, and for land.

There are still groups of people in the world today who do not have elaborate systems of weights and measures simply because they do not need them. In some remote places, where business is just a simple trading of one object for another, where land and food belong to everyone, there isn't any reason to bother.

A weight or measure that started in one country was often carried to others through trade or invasion. Roman



The Romans took their measures into all of these places

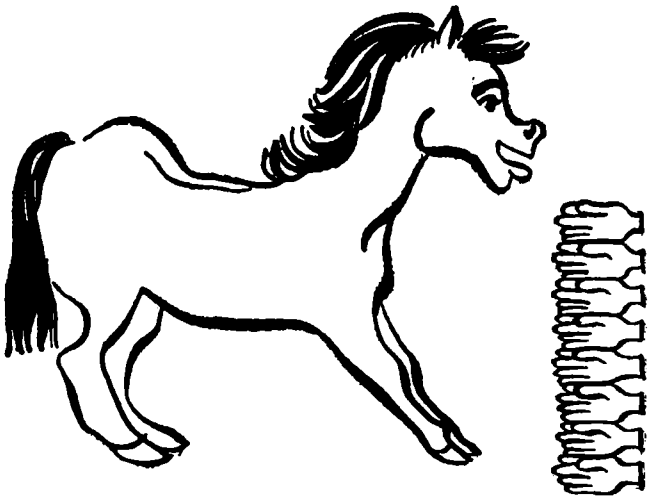
weights, measures, and coins spread into Europe and Western Asia, into England and Africa, when the Romans conquered and occupied these places, and they were the building stones of the local systems. But gradu-

ally, through mistakes in copying and figuring, the standards became so inaccurate and mixed up that many of them dropped out of use. By the sixteenth century most of the people in Europe had returned to the old body measurements.

Some of these earliest measures lasted and we still use them.

People in England still use the *digit*, which is the breadth of a finger, or ¾ inch. We sometimes call a single number a digit.

A *hand* is 4 inches, or the width of a good-sized human hand. Now it is used chiefly for measuring horses, as it



was in the earliest trading days thousands of years ago. The height of a horse, measured in hands, gives the distance from the ground to its shoulder.

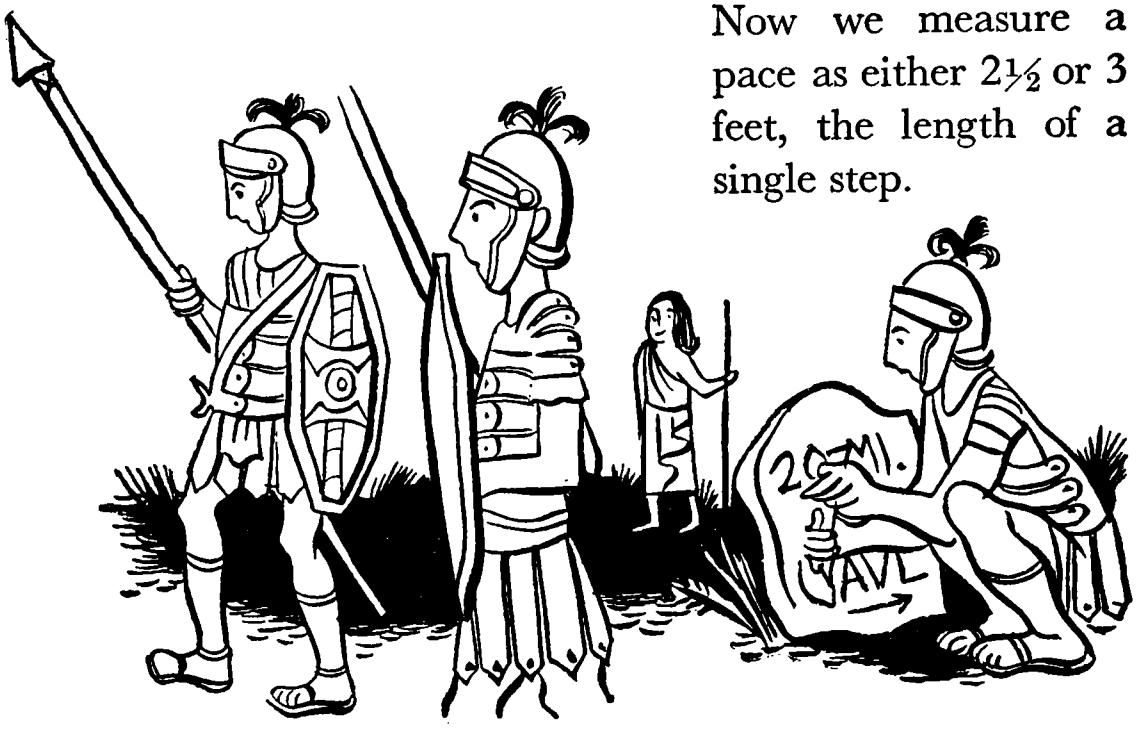
Another measure that started with the hand is the *span*. It began as the distance from the end of the thumb to the end of the little finger when the hand was stretched out fully, and it measures 9 inches.

An *inch* started as a hand measurement too. At first it was the width of a man's thumb. Then it was measured in grains of barley—three of them in a row. That was the way it was made into law by Edward II of England in the fourteenth century after hundreds of years of common use. "The length of an inch," he said, "shall be equal to three grains of barley, dry and round, placed end to end lengthwise."

A *foot* has always been a very common measure. In ancient times it was quite a bit more than 12 inches. Feet must have become smaller when men took to fancier sandals, because by the time the Greeks arrived on the scene the foot was only 11½ inches long. Archaeologists and engineers were able to figure out the length of the foot the Greeks used by studying the ruins of the temples that they built and making thousands of careful measurements of them. The Romans spread this short foot measurement all through Europe, where it is still used today. The 12-inch foot that we use is a standard only in English-speaking countries. In other places a foot may be any length from 11 to 14 inches.

Another common measure was the *pace*. It was the length of a double step counted from the time one foot left the ground until it was put down a second time. A pace was about 5 feet. The Roman soldiers, marching across the countries they conquered, paced off the miles as they went. A thousand paces of the Roman soldiers made a mile, just a little less than the mile we use today. Some of the old Roman markers are still scattered around

Europe to prove it. Now we measure a pace as either 2½ or 3 feet, the length of a single step.



The *yard* seems to have begun in two ways in two different places. In northern Europe it was the length of the girdle the Anglo-Saxons wore. And in the southern countries it was the length of a double cubit. A cubit is 18 inches. One story goes that at the beginning of the twelfth century Henry I of England fixed the yard as the dis-

tance between his nose and the thumb of his outstretched arm.

It is interesting to see that all through history most standards of weight and measure have been fixed not by any parliaments or houses of congress but by the rulers of countries or the headmen of tribes. Most of the common measures have come down through the centuries with few changes since the time of the Saxons. There is actually only about $\frac{1}{100}$ inch difference between the earliest standard yard and our present one.

Ancient weights and measures were invented and used to meet special requirements. When the need for it passed, a measure fell into disuse, just as our modern ones do when they are no longer needed. Once the yard was standardized, there was no need to measure a length of cloth around the elbow, so the ell disappeared. Now coins are worth the amount stamped on them instead of the actual value of the metal of which they are made, so some of the very small weights that money-makers used when they were making coins of little value aren't used any more.

Today there is a constant exchange of goods and materials all over the world, so it is important to have world-wide standards for trade. A ton must be a ton in every port. Land and sea areas must be measured exactly, so that sailors and travelers in every part of the world can depend on any map. Scientists and printers, druggists, engineers and jewelers from every country need exact standards so they can work easily with

one another even though their ordinary language is different.

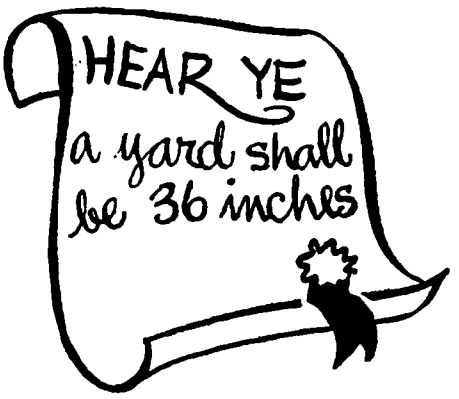
Every trade, science, and profession has weights and measures of its own, and these measures are the language in which their work is done.

SOME THINGS TO REMEMBER

BEFORE WE GO any further, here are some things to remember about weights and measures.

One is the difference between *units* and *standards*.

A *unit* is the value, or quantity, or size of a weight or measure by which the values, or quantities, or sizes of other weights or measures are fixed. This unit is a unit only because the law says so. A yard is 36 inches, a gallon is 4 quarts, only because the law says so. This is true of the pound or the pint or any other legal weight or measure.



A *standard* is the actual physical reproduction of a unit. The yard is a unit of length, but the standard yard is a bronze bar with fine lines engraved exactly 36 inches apart on gold studs set in the bar. All yards must be measured according to this standard.

At the end of the twelfth century Richard I of England made the first law requiring actual standards for length and for capacity, which is the amount a container will hold. These standards were made of iron and were kept by sheriffs and magistrates in different parts of the country. If a tradesman were suspected of giving short measure, his containers or yardstick could be compared with the standards.

When actual standards were first made, no two were ever exactly alike. Nobody could see a difference of $\frac{1}{100}$ inch, and the standard was never used so precisely that it really mattered. But today, when precision machinery is built with standards as measurements, a difference of $\frac{1}{100}$ inch could keep the machines from working properly.

to tenths

Units can be divided in any one of four ways:

Decimally, which means into tenths. The decimal system came down from the Chinese and the Egyptians.

Duodecimally (dew-o-DES-i-mah-lee), which means into twelfths. This was the method used by the Romans. They divided the foot into 12 inches, the pound into 12 ounces, and the year into 12 months.

Binarily (by-NAA-ri-lee), which means into halves, then quarters, then eighths, and so on. This was the Hindu way.

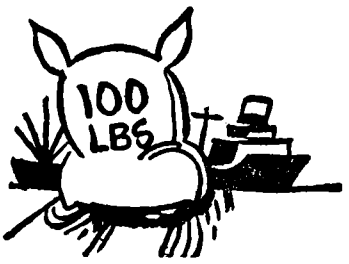
Sexagesimally (seck-sah-JES-i-mah-lee), which means division by 60. This was used by the ancient Babylonians. Time and circles are still divided this way.

More Things to Remember

Another thing to remember is the difference between *weight* and *mass*.

Do you know what weight really is? It is the strength of the pull of gravity on any object.

Mass is the actual quantity of matter or material in the object without regard to its weight or volume. The real measure of mass is *inertia*, the amount of resistance the body puts up before it can be set in motion. Weight changes, but mass never does if the body is not moving. But it has to be moving very, very fast for its mass to change—approaching the speed of light. Except for atomic particles, none of the solid things we measure goes that fast.



The weight of an object changes with altitude. The farther away it is from the center of the earth, toward which the pull of gravity is directed, the less it weighs. If you took a sack of flour that weighed 100 pounds at sea level up a 20,000-foot mountain, it would weigh only 99 pounds and 13 ounces. The same sack of flour would weigh more at the North Pole than at the Equator, be-

cause the earth is slightly flatter at the poles and, therefore, nearer to the earth's center. The weight of the sack of flour might change, but it would still have the same amount of flour in it as it had when it weighed 100 pounds.

So instead of using weight as a standard we use mass, because that doesn't change. Sometimes you may see the word "weight" used instead of "mass." Usually weight and mass seem to be about the same.

Volume is another measurement that's something like mass. Volume is the space occupied by anything. But while the mass always remains the same, the volume can change. If you beat the white of an egg, the volume changes a great deal. It takes up much more space than it did when unbeaten, but the mass or actual amount of egg white is the same.

Weight and mass and volume, length and width and height are being measured all over the world, but the ways of measuring them are not always the same. There are two main systems that are used. Most of the world uses the *metric* system. English-speaking countries generally use the *imperial* system.

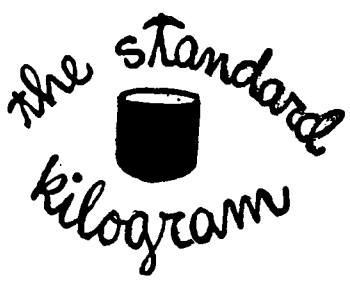
The International Standards

To avoid confusion in international trade the different countries got together and agreed to use a common standard of weight and mass. Because most countries are on the metric system, we use those units and standards.

The *meter* is the unit of length. It is 39.37 inches long.

Once the meter was measured from a platinum-iridium bar, which was kept at the International Bureau of Weights and Measures. But now a way has been found to measure it even more accurately in wavelengths of light, emitted from a special lamp burning a rare type of the gas, krypton (1,650,163.73 of these wavelengths equal a meter). From this is measured the *yard,* which we think of as our unit of length. Before, there were only 30 standard meters in the world, but now a krypton lamp can be used anywhere, under controlled conditions.

The *kilogram* is the metric system's unit of mass. The standard kilogram is a cylinder of platinum and iridium weighing 2.2046 pounds at sea level, and the *pound,* the unit of mass (and weight) of our imperial system, is figured from that.



We did not give up the yard and the pound, which are the units of the imperial system. We just agreed to measure our standards for them in terms of the meter and the kilogram.

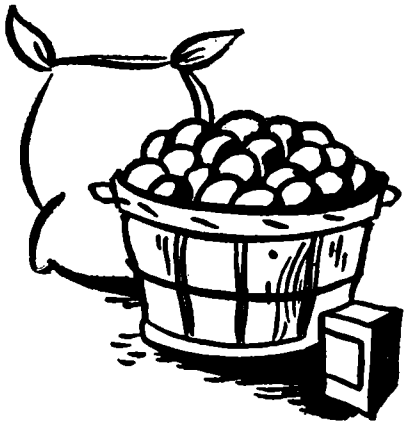
Within the imperial system itself there are other systems of measuring. The *avoirdupois* (av-er-dew-POYZ) system is used for all commodities except drugs, precious metals, and precious stones. These are figured in *troy* weight.

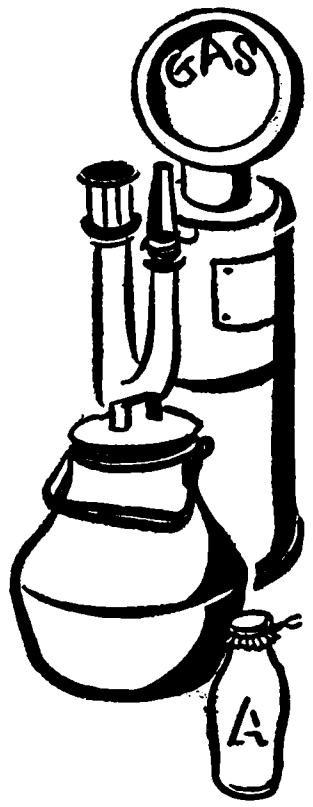
Dry and Liquid Measures

The avoirdupois system can be divided, too—into *dry* and *liquid* measure. Dry measure—a bushel or a peck,

for instance—is used for measuring things like grains, fruits, and vegetables. Liquid measure—perhaps a gallon or an ounce— is used for all liquids.

Sometimes the liquid measures are used to measure dry things, too. You might get a gallon of little onion plants,





or quarts or pints of berries, or ounces of almost anything. But dry measure is never used for liquid things.

Back in the fifteenth century Henry VII of England,

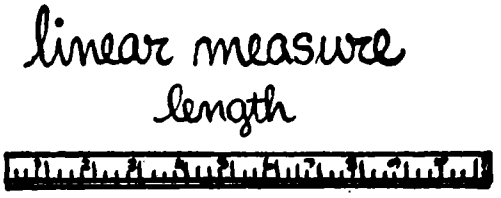
who legally established the first units of weight and measure, said, "Eight pounds do make a gallon of wine, and eight gallons of wine do make a bushel."

In England this single system for dry and liquid measures is still used, but in the United States we have a different system.

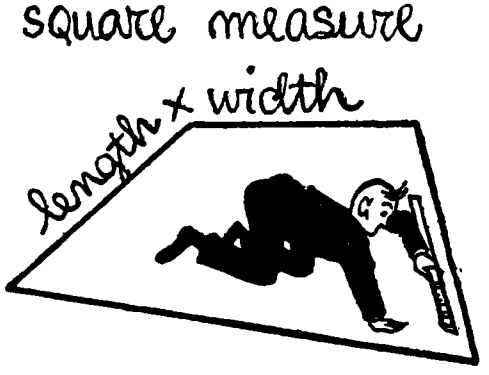
The word *net* after a weight means the weight of the product alone, while the word *gross* counts in the weight of the container.

Ways of Measuring

Linear (LIN-ee-er) measure is the measure of length. A plain ruler gives you linear measure—the distance from the gate to the front door or the length of a kite string.



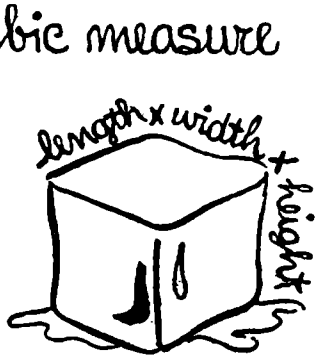
Square measure is figured by multiplying the length by



the width. When the man measures the kitchen floor for

new linoleum, he uses square measure to figure the size of the entire surface that has to be covered.

Cubic measure is figured by multiplying the length by the width by the height of anything. If you wanted to



find out how much ice was in the big block the iceman brought, you would use cubic measure.

TRADE

SHIPPING AND COMMERCE; AVOIRDUPOIS WEIGHT

THE WEIGHT generally used for everyday commerce is called *avoirdupois*. It is a French word and it means "goods of weight." The avoirdupois system of weights is used in all English-speaking countries and in most of those with which they trade heavily. It is used for weighing all commodities except precious stones and metals, and drugs.

The units of avoirdupois weight are:

	Abbreviation
The GRAIN	gr.
The DRAM	dr.
The OUNCE	oz.
The POUND	lb.
The HUNDREDWEIGHT	cwt.
The TON	t.

THE GRAIN

The smallest unit of the system, the basic way of measuring, is called a *grain*. The grain was probably the first standard of weight and it has been used for thousands of years. This standard was originally a grain of wheat taken from the middle of the wheatear. It is the basic unit of all systems of weight, and grains in all the systems are alike. In the imperial system 7,000 grains weigh a pound.

The Dram

There are 27.3437 grains in a *dram*, a word taken from an old Greek one that meant "a handful." It seems odd to have a fraction of such a small thing as a grain, and here's how it happened.

In 1303 Edward I of England established avoirdupois weight for use in commerce. The troy pound, which was used for everything, had 12 ounces. Edward made the

ounces smaller so that the avoirdupois pound was made up of 16 ounces. When the 12-ounce pound was divided into ounces and drams and grains, everything came out

evenly. But in figuring the number of grains in a dram of a 16-ounce pound, there is a part of a grain left over.

Ounces and Pounds

Sixteen drams make an ounce. This ounce started as a Roman weight of $\frac{1}{12}$ pound—in fact, the word means "a twelfth part." The Romans, you remember, divided most of their weights and measures into twelfths. The ounce is still $\frac{1}{12}$ pound in troy weight.

When Edward I established avoirdupois weight, he said that there should be 16 ounces in a pound. The idea wasn't really new—the Greeks had used a 16-ounce pound along with a 12-ounce one, just as we do today.

The Hundredweight

A hundred pounds make a hundredweight. Queen Elizabeth of England gave a little extra measure by adding 12 pounds to the hundredweight. This is called a *long hundredweight* and is very common today. The hundredweight has other names—it may be called a *central* or a *quintal*.

Tons, Long and Short

Nobody is quite sure how the measurement of a ton began, but we do know where. It started in northern Europe. Some people say it started as a tun, a huge cask that was used for holding wine. Other people say it started as a chaldron, a wheat measure that held about 32 bushels.

Twenty hundredweight—2,000 pounds—make a ton, sometimes called a *short ton.* There is another ton, commonly used in commerce, that weighs 2,240 pounds and is made of 20 long hundredweight. This heavier ton is called a *long ton.*

Long tons are generally used in England, while short tons are most common in the United States, Canada, and South Africa. But all these countries and those with which they trade use both of these and several other kinds of tons in their everyday shipping and commerce.

All Kinds of Tons

A *register ton* is the unit of capacity of a ship, of how much a ship will hold. A register ton isn't really a weight, but a measurement of 100 cubic feet. If the length times the width times the height of a certain space in the ship's hold equals 100 cubic feet, that space equals 1 register ton when it comes to figuring how much cargo the ship will hold.

A *displacement ton* is used in figuring the displacement of a ship, which means the amount of water the ship displaces. A displacement ton is equal to an amount of sea water weighing a long ton—about 35 cubic feet of sea water.

Another ton that is a measure instead of a weight is the *cargo* or *measurement ton.* This is a unit of volume, of the space taken up by freight. A cargo ton is figured at 40 cubic feet.

A *kip* is half a ton, or 1,000 pounds. The first two letters

are from the word "kilo," which means "thousand," and the "P" stands for "pounds."

A *last* is a weight that is usually figured at 2 tons, or 4,000 pounds, but which varies in different countries for various commodities. The word "last" itself originally meant a load of cargo and it is often used as a unit of ship capacity of 1 or 2 tons.

Here are some of the other things that a last might mean:

Of grain, 82½ bushels in the United States, 80 in England.

Of gunpowder, 24 barrels, each weighing 100 pounds.

Of herring, 10,000, 13,200, or 20,000 fish.

Of hides, 12 dozen.

Of wool, 12 sacks.

Of flax or feathers, 1,700 pounds.

Large measures are commonly divided into *quarters*. A quarter may be

A quarter of a ton, 500 pounds,

A quarter of a long ton, 560 pounds, or

A quarter of a hundredweight, 25 pounds, or a long hundredweight, 28 pounds.

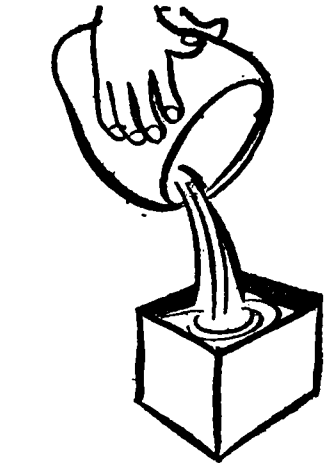
About Capacity

Capacity, the amount a container holds, is a very important measurement. In the beginning the measures of capacity were natural objects—gourds or big clamshells

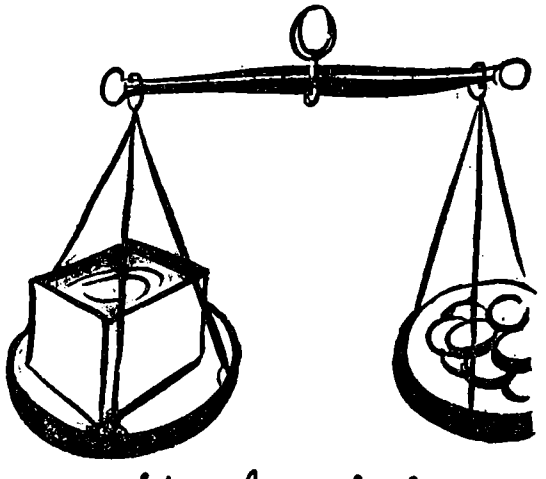
or eggshells. But natural measures of capacity varied—some gourds were large and some were small—so it was necessary to invent one that would be a standard. Then buyers and sellers could know exactly how much it held.

The first exact measure of capacity was used in Babylon. It was a hollow cube, each side of which was a handbreadth long. This cube, filled with water, was the

Babylonian unit of capacity. Its capacity was the amount of water it held.



a unit of capacity

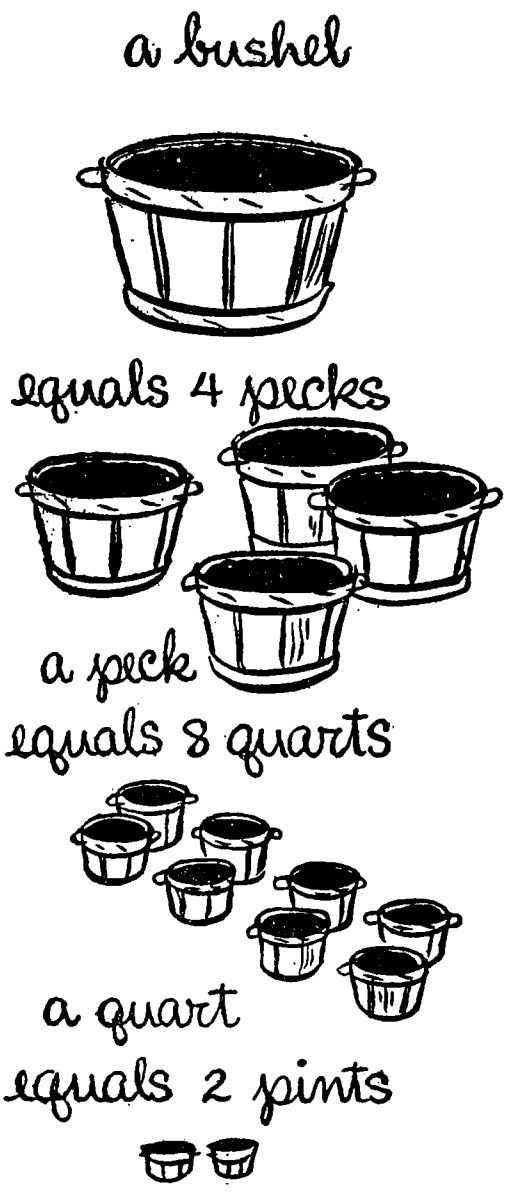


a unit of weight

Water is still used as a standard for measuring capacity.

The weight of the cubeful of water became a unit of weight, too.

Most of our measures of capacity today are measures not only of the amount they hold but also of the weight of that amount. For instance, a bushel basket holds a certain amount of grain, and a bushel of grain has a definite weight by law.



Bushels and Bushels

The *bushel* is a dry measure used for things like grains or fruits and vegetables. A bushel is the largest dry measure. A pint is the smallest.

Two pints make a quart.

Eight quarts make a peck.

Four pecks make a bushel.

The bushel, as a measure, seems to have changed a good deal since it started, because the word came from an old Celtic one that meant "the hollowed hand." (The Celts lived in the British Isles and northern

Europe.) It would take quite a number of hollowed handfuls to make a bushel today.

The American and English standards part company at this bushel measurement. The American standard bushel contains 32 dry quarts, while the English imperial bushel holds 33.026 quarts. The American standard bushel is the same as the old British Winchester bushel that was used back in the days when Henry VIII was a little boy.

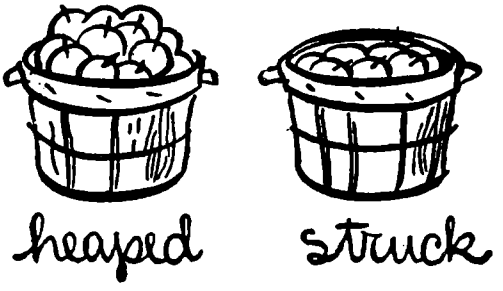
When America was first settled, the colonists, being mostly English, naturally used the English weights and measures that they were used to. After the United States became independent, these standards were so much a part of business that they were adopted without any changes. We still use those original measures, but in the nineteenth century England revised some of hers. That is why, even though we use the same system, there are differences in certain standards.

Though the people in the various colonies had brought their weights and measures from England, the same weights and measures had different values, depending on what part of the British Isles the settlers had come from. Even after the United States had been a country for more than a quarter of a century, the states were still using these varying measurements. If a man in Maine sold 50 bushels of grain to a man in North Carolina, the North Carolina man felt cheated because, according to his measures, he had received only 48 bushels.

Now the United States Bureau of Standards sends an

exact bushel measurement to each state, and trade between the states must be based on that bushel.

But in some states a bushel basket of apples is measured in *heaped measure*, which means that the apples are piled high in the basket. Other states use *struck measure*, where the apples are level with the top of the basket.



The weights of bushels of different commodities vary. A bushel of something light and bulky, like charcoal, weighs only 20 pounds, while a bushel of salt weighs 80 pounds. So the law has fixed a definite weight for a bushel of each commodity, varying only where states use heaped or struck measure.

A special measure of about 8 bushels is called a *seam*. At first it was the amount that could be carried on a packsaddle, so it, too, varies with different commodities. A horse can carry different amounts of different things.

A *peck* is ¼ bushel, 8 quarts dry measure. Once it was just a special-sized pot used for measuring grain.

A *quart* is 2 pints, ⅛ peck dry measure. In liquid

measure it is ¼ gallon. The word is short for "a quarter part."

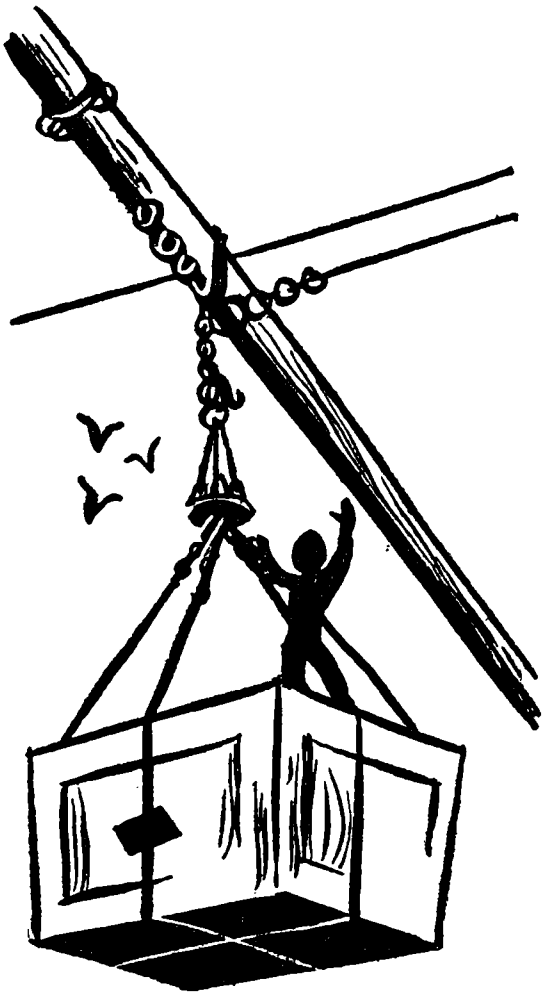
A *pint* is ½ quart in both dry and liquid measure. It was originally a little measure for wine.

The Gallon

The gallon has been a measure for so long that nobody seems to know where it began. Both American and British gallons contain 4 quarts, but the British imperial gallon is ⅕ larger than the United States standard gallon. The American gallon is exactly

like the old English wine gallon, which had 32 ounces to the quart. The British imperial gallon has 40 ounces to every quart.

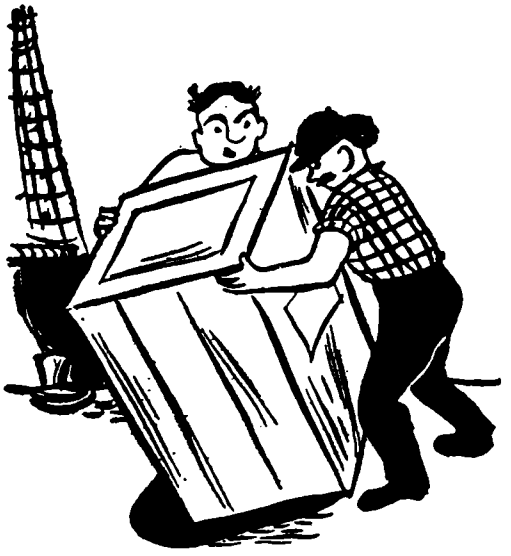
Another British gallon, called the *barn gallon*, is 2½ times larger than the imperial gallon and is usually used for measuring wine.



Dividing any unit is a matter of convenience rather than law. Because certain units have been divided in certain ways for centuries doesn't mean that they can't be divided in any other ways. We usually divide a gallon into quarts and pints, but in gasoline pumps gallons are now divided into tenths. It's handier to count the price that way.

Something about Containers

As ways of doing business have changed, units have changed, too. Now that there is machinery to lift huge loads, freight and produce can be packed into giant containers that are hoisted aboard ships and freight cars with cranes. When men had to load cargoes without this machinery, the containers had to be much smaller.



There are still things that must be handled partly by hand, and they come in much smaller containers than before. In the old days laborers had to strain over huge

casks and bags. Now most food and produce are packed in containers that are not so hard to lift.

Changed ways of living change container sizes too. When families were large and houses had plenty of storage room, people bought flour and sugar in 100-pound barrels, potatoes and onions in 100-pound bags. Now these things come packed in much smaller quantities. Not only is there less space in which to store great amounts of food, but there is no necessity for it. If there isn't a market right around the corner, then modern transportation provides a fast and easy method for getting to one.

The Bag

A great many products are measured by the containers in which they are shipped. Various sizes of containers are handy for special things, so often a container of a certain size is almost a standard for a certain product. But you can't depend on it!

Suppose you were shopping around for a bag of coffee. If you bought it in Brazil, it would weigh a little over 132 pounds net. (Not counting the bag—remember?) If

you went to Colombia or Costa Rica for your bag of coffee, it would weigh 140 pounds gross. But if you bought it from a merchant in Mexico or Nicaragua or Venezuela, it would weigh 145 pounds gross. And if you finally decided to buy your bag of coffee in Guatemala, you would have 160 pounds gross.

So you can see that when the word *bag* is used as a measurement, all you really know about it is that you have a closed paper or fabric container. You'd have to find out how big the bag was, what was in it, and where it came from before you'd know how much it held. Sugar

and wool, cement and cocoa are all sold by the bag, and none of these bag weights are the same. You couldn't depend on even a simple bag of flour. The English sometimes pack their flour in such big bags that they weigh six times as much as bags of flour in the United States.

The size of the bags in which produce is packed changes with the times, too. When food is scarce and expensive, it is packed in smaller quantities. Then, if your grocer can't afford a 100-pound bag of onions, he can buy a 50-pound bag.

A *sack* is not a fixed measure in the United States, but it is usually about 3 bushels.

A sack of flour is 100 pounds if it is going to be sold here and 140 if it is going to be exported.

A sack of cotton is 140 pounds, too, but a sack of salt is 315 pounds.

The Barrel

The *barrel* is another container that is a weight and a measure, too. Barrels of different things are different sizes, but barrels of the same thing usually weigh a standard amount.

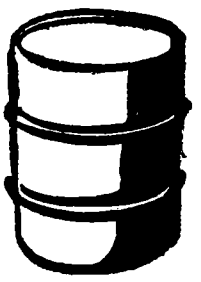
A barrel of beef or pork or fish weighs 200 pounds.

A barrel of flour weighs only 196 pounds, but this weight has been used for so many hundreds of years that

nobody thinks of changing it. Flour was first weighed against one of the oldest weights we know, the *stone*. Long ago goods really were weighed against stones instead of the metal weights we use now. One particular size of stone weighed about 14 pounds, and that weight is still used today and is still called a stone. For hundreds of years a barrel of flour has weighed 14 stones, or 196 pounds.

Fruit and vegetables by the barrel aren't measured by weight at all, but by inches. A fruit or vegetable barrel must hold 7,056 cubic inches of produce.

If a barrel is for liquids, it is measured in another way, by gallons. Most barrels used to hold a little more than 31 gallons. But now, so they will be easier to lift and handle, 15-gallon barrels are generally used.



Oil is usually shipped in a special metal barrel called a *drum*, which holds from 50 to 55 gallons.

A *hogshead* is a much larger cask, and in different parts of the world a hogshead might be any size from 63 to 140 gallons. A hogshead may be used for liquids, or for dry things—tobacco, for example. Nobody knows where it got its name. A *pipe* is 2 hogsheads—the small ones. It holds 126 gallons.

Another kind of large cask, usually used for shipping wine, is called a *butt*, and it holds 130 standard gallons. The Greeks were the first to use the butt, and from that word came the name of one of our commonest containers—the bottle, of course.

Baskets

The amounts held by different kinds of baskets are set by law.

Farmers pack bunches of grapes, for instance, in *climax baskets*, the long ones with handles and solid bottoms. Climax baskets may hold anything from a half pint dry measure to several quarts.

Round stave baskets, the big kind that apples are sold in (and that your grocer sometimes uses to deliver your groceries in), are bushel baskets.

And when you buy a *splint basket* of strawberries, you are getting a pint or a quart.

Counting

In doing business, a great many things are counted instead of being weighed or measured. The commonest way of counting is by the *dozen*, which is 12.

The Romans did most of their business in dozens—it was a natural part of their duodecimal system. ("Duo" means "two" and "decem" means "ten," in Latin, the Romans' language.)

A dozen is handy for buying eggs or rolls, but suppose you had a store and were buying a great number of things—you would buy them by the *gross*, which is 12 dozen, or by the *great gross*, which is 12 gross.

Another way of counting, which isn't used much in business, is by the *score*. A score is 20. When Lincoln said, "Fourscore and seven years ago," he meant 87 years.

Some Funny Ones

The *catty* is a Chinese unit of weight for rice. We don't use it, but it's fun. The unit itself grows smaller between the rice field and the port. As a coolie carries the rice bags to market, he takes out his pay in rice. The rice bags reach the market weighing less than they did when they started but still measuring the same number of

catties. The rice that the coolie has taken out doesn't count.

A *hand* is a measurement of bananas. It is an amount you might buy—one of the small bunches that grows on the big bunch. But people in the banana business never use the word "bunch." The whole big bunch of bananas is called a *stem*. And the separate bananas on the hand are called *fingers*.

A *cran* is a very particular measurement. It is used only for fresh herring. A cran of herring is 45 gallons. The Gauls first used the word "crann" as a measure and it meant "a lot." A cran is certainly a lot of herring.

A *firkin* is a British weight for butter—56 pounds of it. Sometimes, though, a firkin is 9 gallons, or ¼ barrel.

A *frail* is 50 pounds of raisins. Originally it was a rush basket that was used in the Mediterranean countries for figs and raisins. The basket has disappeared, but the amount it held is still called by its name.

A *clove* is a British measurement for cheese or wool—8 or 10 pounds of either.

A *ship pound* isn't a pound at all, but a unit of weight varying between 300 and 400 pounds.

Did you know that a *barge* is an exact measure, not just a boat for carrying goods? At one time it must have been the load carried by a barge of a certain size, because a barge of freight weighs 21.2 long tons.

A *baker's dozen* of anything isn't 12 at all, but 13. It

started back in the time of Oliver Cromwell, when bakers were ordered to make their rolls smaller in order to save

flour. The customers were so angry at getting less for their money that to keep their good will the bakers threw an extra roll into every dozen.

MONEY, JEWELS, AND PRECIOUS METALS; TROY WEIGHT

Have you ever thought about what business must have been like before people used money? They had to trade.

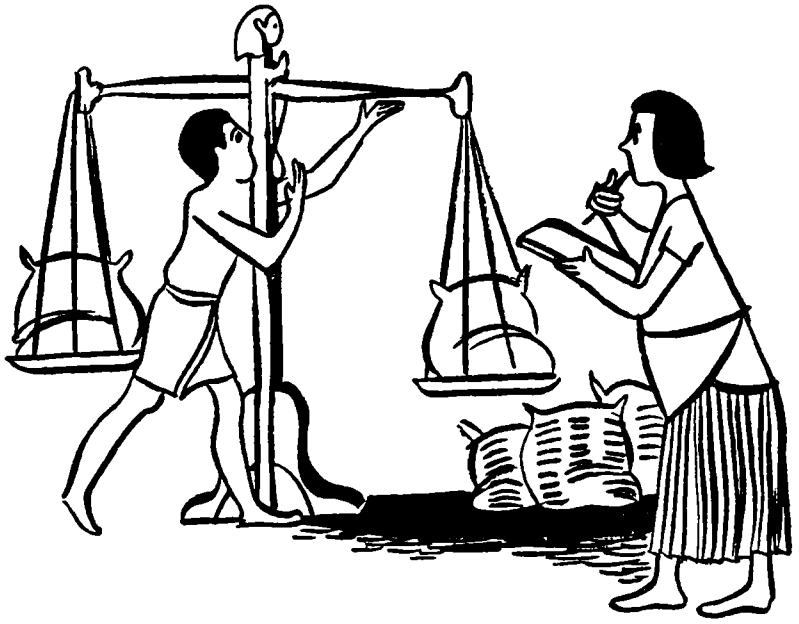
If you had an extra ox and needed a sword, you tried to trade the ox for the sword. There was no such thing as "change." Your ox might be worth more than the other man's sword, but you couldn't get a sword and a half for it any more than you could give him three-quarters of an ox. The only thing he could do would be to throw in a belt or a pair of sandals to even things up.

Wherever people kept oxen and cows, they were the very earliest units of wealth. Even when gold first came

into use, its value was reckoned by how many oxen or cows an amount of gold was worth. (Later, when coins were made, some of the early ones were just rough copper bars stamped with a picture of an ox.) Today we think in exactly opposite terms. We think of how much gold a cow is worth. But in those very early days cows were money. You could exchange them for anything you needed, even if you couldn't take them to market in your pocket.

Sometime between 8000 and 7000 B.C. the Egyptians got the idea that gold, which they knew was rare and therefore valuable, could be exchanged for other things.

They did not know how to mine gold at first. They got their earliest supplies by chasing the Nubians and taking away their gold beads and ornaments.



Naturally they couldn't get too much gold this way, so they ground it up and used small amounts of gold dust to exchange for goods. They measured this gold dust by the amount that a goose quill would hold.

Gold was the first material for which a system of weight was found. A primitive balance scale came into use with seeds of plants weighed against the gold. This use of seeds as the earliest weights has come straight down to us through thousands of years. We still use the grain, which is a seed, as a weight for gold, as well as the carat for gold and precious stones. The carat was a kind of very small bean the Arabs used.

After they started mining gold, the Egyptians measured large amounts by the sack or *heket*, a common

measure something like our bushel. Then they discovered an interesting thing. Two hekets of gold were not always equally heavy, even though their size was the same. The gold in their mines was sometimes fused with silver in a natural mixture called electrum. But since silver is much lighter than gold, this gold and silver mixture was not as heavy as pure gold. So the only way they had for testing the purity of their gold and determining its value was by weighing it. They used little stone weights. The earliest known Egyptian standard of weight was called a *beqa*. It was a short cylinder with domed ends and it weighed less than ½ ounce.

These weights for gold were the ancestors of all the weights in the world, and the gold beads that the Egyptians took away from the Nubians were the beginning of money as we know it today.

There is a special system used for weighing precious metals, called *troy weight*. Some people think that this system started in the town of Troyes (tro-WAH), France, but nobody is quite sure. By the fourteenth century troy weight had become quite well known in England. The English kings used it to count the royal treasure, and in 1527 it became the legal standard for minting coins. But it was

in common use long before that. In 1266 Henry III had said, "An English penny, called a sterling, round and without any clippings, shall weigh 32 wheatcorns in the middle of the ear. Twenty pence do make an ounce, and 12 ounces a pound. . . . " Some of these measurements are the same in troy weight today.

The units of troy weight are:

	Abbreviation
The Grain	gr.
The Pennyweight	dwt.
The Ounce	oz.t.
The Pound	lb.t.

The Grain

The smallest unit of troy weight is the grain, as it is in avoirdupois weight. But there are only 5,760 grains in a troy pound instead of the 7,000 in an avoirdupois pound.

The Pennyweight

Twenty-four grains make a pennyweight, which was the weight of the English penny at the time troy weight became the legal standard.

The Ounce and Pound

Twenty pennyweights, or 480 grains, make a troy ounce. We said that the word "ounce" originally meant "a twelfth part," and an ounce was a twelfth part of a Roman pound. Twelve ounces make a pound in troy weight, too.

Troy weight is the basic system, but there are other units of weight used by money-makers and jewelers. Here are some of them.

The *barleycorn* is another word for grain. Sometimes a grain of barley was used instead of a grain of wheat, but the weight is the same—$\frac{1}{24}$ pennyweight.

A *carat* is the unit of weight for precious stones, especially diamonds and pearls. It was originally measured by a bean or pea shell weighing 4 grains, but it has since been standardized at 3.086 grains. A carat is still usually divided into four parts, though, for handier measuring, and these parts are called *carat grains*. Sometimes a jewel weighs more than an even number of carats. Jewelers say "a carat and an eighth" or "two and $\frac{1}{32}$ carats."

Grading precious stones according to carats is a long and tedious job, and there is a story about how this fact once helped Cecil Rhodes to keep a corner on the diamond market. Because he owned the largest diamond mines in the world, he was able to control the price of diamonds everywhere by releasing just a few at a time and so keeping the price very high. The owners of a number of other mines got together and decided to break his power by pooling all their diamonds and throwing a great number of them on the market at once. They called Mr. Rhodes in and showed him the hundreds of diamonds, all carefully graded, set out on a long table. As he rose to leave, Rhodes bumped into the table and knocked it over, scattering the diamonds in every direc-

tion. It took years to sort and grade those diamonds again, and by that time Mr. Rhodes didn't care.

A carat is also used in measuring the fineness of gold. For the sake of convenience pure gold is divided into 24 parts, each part called a carat. This measurement is used in expressing the fineness of any mixture of gold with other metals. When you see something marked 14-carat gold, it means that out of a weight of 24 parts there are 14 parts of pure gold mixed with 10 parts of another metal. Twenty-two-carat gold is almost pure gold, with 2 carats of another metal added just to harden it. This measuring of the fineness of gold was what the Egyptians were after when they first started weighing.

Sometimes you see carat spelled with a "K." This comes from the name of the bean the Arabs first used as a weight for gold, the karob bean.

The minter, the man who coins money, uses the *mite*, a measure of $\frac{1}{20}$ grain. People speak of a mite when they mean a very small amount of anything. Thousands of years ago it was the name of a coin of very small value. If you remember, the Bible talks about the "widow's mite."

Sterling is the measurement for purity of silver. It used

to mean that the silver was 0.925 pure. Now the standard for sterling is 0.50 silver. Back in the thirteenth century the English penny was called a sterling.

About Money

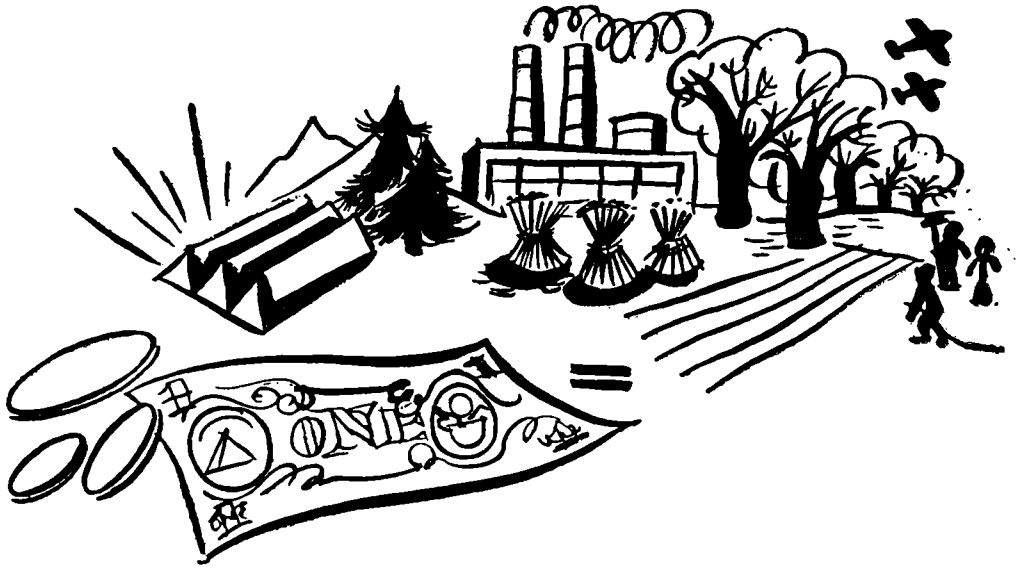
For a long time precious metal, like jewels, was an article of trade. People traded gold for a cow and then the cow for cloth or jewels. They didn't measure the worth of all these things in precious metal. They didn't have any one common thing that they could exchange for anything else they wanted, the way we use money today.

Finally they did get around to using their precious metal as a *medium of exchange* for other things, but they always exchanged an equal value of metal for whatever they were buying for it. Did you ever realize that we don't do that today?

The ancient Greeks were the first people to use coins with the value they represented stamped on the coin face. After that it wasn't necessary to weigh gold every time you made a business deal—its value was written right on it. And each coin actually contained its face value in precious metal. To prevent this metal from being pared away, money-makers started milling the edges of the coins—making those little ridges we still have on the edges of our silver coins. Coins that were worth large amounts were made of pure gold. Coins of small value were of silver and no bigger than your smallest fingernail.

Nowadays metal money isn't actually worth the

amount stamped on the coin. The money used in each country can be exchanged for a reasonable amount of goods only when the country is prosperous and business

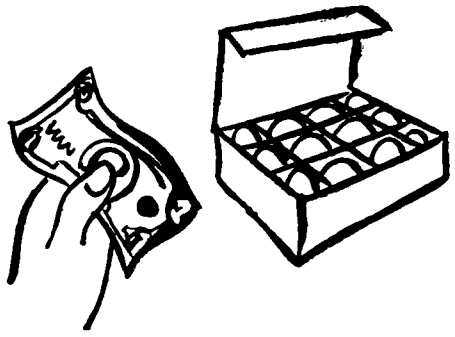


is good and the money is backed up by things of real value.

Every country in the world has its own units of money, regulated by law. The law says how much precious metal must go into each coin and how much gold, property, and treasure must back up every paper note. For, of course, paper money has no value by itself. It would be worthless unless it represented things of real value that are too bulky or impossible to trade.

When there is inflation, money doesn't buy very much. Sometimes that's because there is more money

than there are things to buy with it. When this happens, prices go very high. Once in a while it's because a government has printed money that isn't backed by any real treasure and the people know it. Whatever the reason, the less you can get in exchange for your money, the less it is worth. Money today, like money 5,000 years ago, is good only when it can be traded for real things.



The different coins and values of money in most countries have come down through many years of use. Now they are very carefully regulated by law. Here are some of the units of money in the United States and how they got that way.

The *dollar* is our main unit of money. The American dollar started as the Spanish peso when Florida and the West Indies were settled by the Spanish. This peso was worth eight Spanish reals, smaller Spanish coins, each equal to about 12½ cents. That's why the pirates who sailed the Spanish Main (we call it the Caribbean Sea now) called dollars "pieces of eight."

The slang word for a Spanish real was a "bit." When there weren't any bits around, people cut their dollars into four parts, which made each part worth two reals, or two bits. We still use that slang today. A quarter of a dollar is two bits, a half dollar is four bits, and 75 cents, or three-quarters of a dollar, is six bits.

The first United States silver dollar was minted in 1794 and was modeled after the Spanish peso. That dollar was called the "pillar dollar" because it had two pillars embossed on it with a ribbon twined around them. That was the beginning of our dollar sign—$. See?

There was a reason for using the peso as a model for our dollar. During the Revolutionary War the Continental Congress had promised to pay all obligations in Spanish dollars. Up until 1873 this silver dollar was our legal monetary unit.

The silver dollar really contains only about 46 cents worth of silver. The half dollar, the quarter, and the dime

(which means a tenth) are all just portions of the dollar, as their names show. Each one is worth about half its face value in silver.

The nickel and the penny are both made mostly of copper. Actually, they are not worth much of anything. Because of this there is a law that says you can refuse to

The United Colonies
SIX DOLLARS
No 15475
SIX DOLLARS
THIS Bill entitles the Bearer to receive SIX SPANISH MILLED DOLLARS, or the Value thereof in GOLD or SILVER according to a Resolution of CONGRESS published at Philadelphia Nov 2: 1776.
PERSEVERANDO
SIX DOLLARS
VI SIX DOLLARS

accept more than a quarter's worth of nickels or pennies in payment for anything. But because people know that the government stands behind the face value written on those coins, they hardly ever do refuse to accept them.

When people do stop believing in the money of a country, they stop using it and go back to the old system of trading. They may exchange a baby carriage for a bicycle or a sweater for a pair of shoes. Sometimes one thing that everybody wants becomes a form of money that can be exchanged for anything else, like cows were

in the beginning. Cigarettes may be money, or coffee or stockings or anything at all that is scarce and in great demand.

People are exchanging real things for real things, even if they are not actually of equal value. When nobody believes in the actual money of the country, a bushel basket of it might not be enough to buy a candy bar.

APOTHECARY WEIGHT AND LIQUID MEASURE

Until 1617 in England you could buy drugs and medicines not only from apothecaries (ah-POTH-eh-ker-eez)

but from grocers, too. All of them mixed up prescriptions in any way they thought best, using widely varying quantities and strengths of drugs.

But in 1617 the apothecaries (we call them "druggists" or pharmacists) got a separate charter from the king, and no grocer was allowed to keep an apothecary shop. Physicians brought a lot of pressure on the apothecaries to make all of them fill prescriptions the same way. But there were no generally accepted formulas in use.

In 1618 the physicians made up a recipe book for making prescriptions called the *Pharmacopoeia* (far-mah-koh-PEE-ah). The College of Physicians sent special agents to examine the apothecary shops, and these agents had the power to destroy any compounds they found that had not been prepared according to the recipes of the *Pharmacopoeia*. Today the *Pharmacopoeia* is the legal standard for drugs and chemicals. There are British, French, Spanish, and United States Pharmacopoeias.

Early in the twentieth century an international conference at Brussels, Belgium, set up standards for many of the basic drugs. Now the United Nations has a special group whose job it is to agree on international standards to be used in the various national Pharmacopoeias.

Before 1825 in England physicians and apothecaries used an old system of weights and measures that was based on troy weight and the old wine gallon. Then laws were passed that set up standard weights and measures to be used for drug purposes. Today, in addition to their own apothecary system, pharmacists use the metric system and occasionally troy and avoirdupois weights.

Apothecary weights are usually indicated by symbols and Roman numbers instead of regular abbreviations.

The basic unit of apothecary weight is the same as that of the other systems, the *grain.*

Twenty grains make one *scruple.* A scruple was originally a small pointed stone that was used as a weight for very tiny quantities. The sign for a scruple looks like this ℈ and a half scruple like this ℈ss.

Three scruples, or 60 grains, make a *drachm,* or *dram.* Remember that word "dram"? The Greeks called it a *drachma,* or handful. Sometimes, in old apothecary books, you can see the word "drams" written as *drachmae,* just as it was when this way of measuring first started. The symbol for a dram in apothecary's weight is ʒ.

Eight drams equal 1 ounce apothecary, or ℥.

Twelve apothecary ounces are equal to 1 pound, as they are in troy weight. An apothecary pound is written like this, ℔.

Apothecaries often use liquid measures in making up your prescriptions. The smallest liquid measure is a *minim,* which is just about one drop. It is written ♏.

Sixty minims make 1 fluid dram. Your doctor writes fʒ.

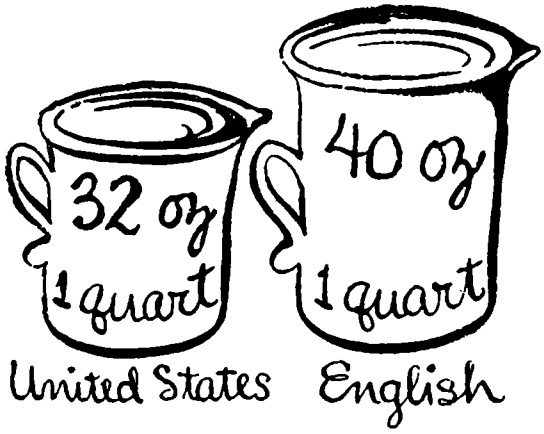
Eight fluid drams make a fluid ounce, or f℥.

Four fluid ounces make a *gill,* which is a very old small measure that isn't used much nowadays. In the beginning it was the amount of one drink of wine. A great many measures started as measures of wine.

Two Kinds of Pints and Quarts

Four gills, or 16 fluid ounces, make a pint in the United States. In England it takes 20 fluid ounces of the same size

to make a pint. Two pints equal a quart, but you can see that the United States quart and the English quart are quite different. One has 32 ounces, the other 40 ounces. Four quarts equal one United States gallon, but the English use the imperial gallon, which is equal to 1⅕ United States gallons. A United States gallon of water weighs 8⅓ pounds, while an imperial gallon weighs 10 pounds.



You can see why an apothecary today thinks these varying weights and measures are confusing and, like his fellow apothecaries around the world, is starting to use the international metric system more and more.

THE THINGS WE WEAR

The trades that make the things we wear are very old. Here are some of their measurements, most of which have been used for hundreds of years.

Raw Materials

Of all the *bag* measurements, a bag of wool is the biggest. It weighs 364 pounds.

The English have another bag of wool, which holds 182 pounds. They call it a *pocket*. The little pockets we have in our clothes today all started as enormous bags and pouches for carrying merchandise. Gradually pockets shrank until they were small enough to be carried by hand or hitched onto a belt. And finally they were sewed right into the clothes.

A *sack* is different from a bag. A sack of cotton weighs 140 pounds in the United States and twice as much in England.

Usually, though, cotton is measured by the *bale*. Before people ever thought of putting their raw materials into any kind of container, they baled them—tied them

together into big bundles for shipping or storing. Many kinds of things, from cotton to hay, are baled.

All the countries that grow cotton pack it in bales, and each country has its own bale weight. A bale of cotton from the United States weighs 500 pounds; one from Egypt, 740; from India, 400; and from Brazil or Peru, 250 pounds.

Sometimes cotton is measured by the *block*, a few hanks, which are big coils of yarn, tied into a bale of about 5 pounds.

A *sarpler* is a bale of wool that weighs a long ton, 2,240 pounds.

Very often raw materials are measured by the *last*, which at first was just another word for a load. In an earlier chapter we said that

A last of wool is 12 sacks.

A last of flax, from which linen is made, is 1,700 pounds. A last of feathers is 1,700 pounds, too.

A last of leather hides is 12 dozen.

Yarn

When the raw materials are finally spun into yarn or thread, there is another whole set of measurements for

that. You hear a lot about *denier*, and that is one of the most important of all.

Denier (deh-NEAR) is the measure of weight for all silk, rayon, and nylon yarn. When Francis I started the modern silk industry in sixteenth-century France, he looked around for a weight to use for the silk thread. He finally decided on an old silver Roman coin about the size of a fingernail. The coin was called a denier.

a denarius or denier

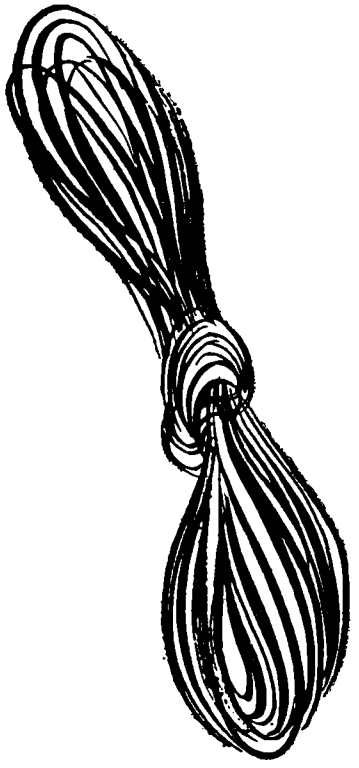
A thread of 1-denier size would measure about 4.5 million yards to a pound. And one pound of 1-denier yarn would be about 2,530 miles long. As the denier size gets larger, the number of yards in a pound gets smaller. The higher the denier size, the thicker the yarn is.

All through the textile industry there is a relationship between the length of yarn and its weight. The English yard and pound are the standard for numbering spun yarns all over the world. They are numbered according to the number of yards to the pound. This count is expressed in deniers.

A *typp* (TIP) is the unit of count for all yarns. It is the number of thousands of yards of a particular yarn that weigh one pound. The funny-looking word is built out of the first letters of its meaning—Thousand Yards Per Pound.

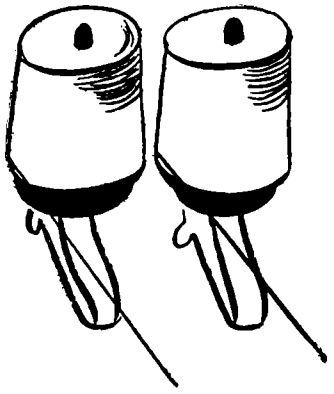
Sometimes the form in which yarn is put up is used

as a measure. Often it is put up in a sort of knot called a *skein*. Skeins of various materials have different lengths, but a skein of cotton yarn is always 360 feet.



A larger kind of skein is called a *hank*. There are 840 yards of cotton yarn in a hank and 560 yards of woolen yarn.

As it is spun, yarn is wound onto a rod called a *spindle*, and this is used as a measure, too, because it



holds a certain amount of each kind of yarn. There are 15,120 yards of cotton yarn on a spindle and 14,400 yards of linen.

Here are some other measures of yarn.

A *thread* of cotton is 1½ yards.

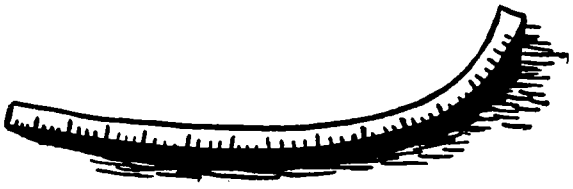
A *lea* is a common measure, varying for different types of yarn. A lea of silk or cotton is 120 yards; of linen, 300.

Thirty yards of linen yarn are called a *cut*.

A *heer* is a measure so old that nobody knows where it started. It is 600 yards of wool or linen yarn.

Measuring Cloth

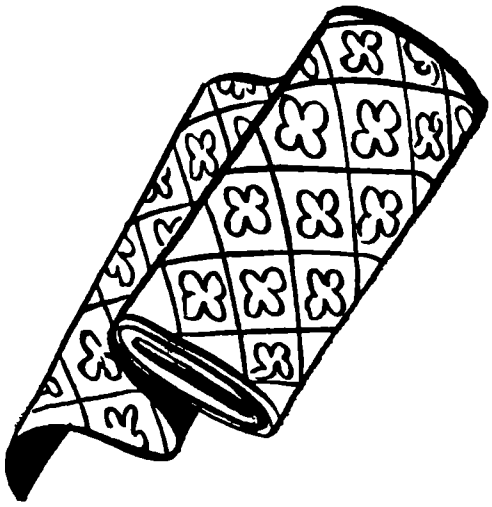
The *yard* is the standard on which most of the textile business is done and it measures 36 inches. For making finished clothes out of cloth there are different kinds of guides for measuring off yards. A yardstick is just 36 inches long. Most tape measures are 60 inches long, though once in a while you see a shorter or a longer one. For making patterns where measurements don't run in straight lines there are special curved yardsticks that look like this.



An old measure of cloth that was used before the yard was the *ell*, which might be anything from 24 to 48 inches. In some places where the name is still used it is a modern meter. The ell has been used as a measure since Biblical times. It was first measured from the hand, around the elbow, and back to the hand again, which is a pretty convenient way to estimate a length of goods. In the

tenth century King Edgar of England standardized the ell at 36 inches, so that it became a yard.

The shape of a *bolt* of cloth gave it its name. The material in it is so tightly rolled that it looks like a long, flat club. A bolt of cotton is about 40 yards, of wool about 70. Depending on the materials, bolts of goods have different widths. Silk or cotton dress goods are generally either 30 inches or a yard wide. Woolens are 60 inches wide, and upholstery materials are woven in 54-inch widths.



Sometimes a special piece of cloth of a new design is run off to test the pattern for effect and to see how it looks made into a dress. This is called a *book* or *run* of goods. To allow plenty of material for trying it out, a book is usually about 50 yards. A *cut of goods* is about 5 yards, or enough to make an average dress.

Cloth into Clothes; Pattern Size

Pattern size in suits or dresses is not an exact measurement. Each manufacturer has his own patterns, made

with his own variations. In making dresses one manufacturer's size 12 may have a waistline smaller by an inch or two than another's, or it may be longer or bigger in the shoulders. The variations change from year to

year with the styles. Patterns for dresses that are made for "juniors" are very different from patterns made for mothers and grandmas. They are different shapes in different places! The size numbers run differently, too. Sizes for juniors run 9, 11, 13, and so on. Regular sizes run on the even numbers—10, 12, 14, and up the scale.

Patterns for larger figures have larger numbers—36, 38, 40. Some dresses are made in "half sizes," too.

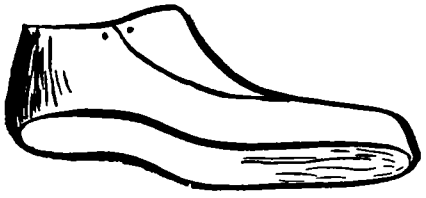
When a new pattern is made, a standard—perhaps a size 14—is made first. Then the larger and smaller sizes are figured from the standard. This is called *grading*.

There is a special way of measuring the buttons that go on your clothes. The size of a button is measured by its diameter, or the width across the button. The unit of measurement is called a *line*, and it is $\frac{1}{40}$ inch. So a 16-line button would be 16 times $\frac{1}{40}$, or $\frac{2}{5}$ inch wide.

this is a 20 line button

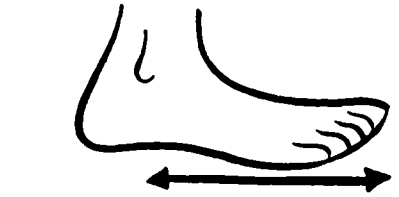
Shoes

The patterns for shoes are wooden forms called *lasts*, and like dress patterns, the lasts of various companies are different. You have probably heard someone say, "Oh, I can't wear their last," or "That shoe store's last is perfect for me." Even if the size is right, the shape of the form on which the shoe is made doesn't fit all shapes of feet. The size of the shoe is usually a little bigger than the size of the last to allow for the movement of your foot inside.



When your foot is measured for a pair of shoes, you

step on a ruler that is measured off in inches, by eighths of an inch. If you look at the ruler carefully next time, you will see why your shoe size is not the actual number of inches in the length of your foot. The place where you put your heel is blank. The measurement starts right



Shoe size is measured from here to here

underneath the arch of your foot. So if you wear a size 6, the distance from your arch to the end of your toe is 6 inches.

The width of your foot is measured, too. Foot widths run from A to E, like a report card. An EE is a very wide foot, and for very narrow ones there are double A's and triple A's, all the way to AAAA.

The thickness of leather used for shoes is measured in *ounces*. An ounce is $\frac{1}{64}$ inch in shoemaking. But for measuring the thickness of leather that is going to make the soles of the shoes, there is another special unit called an *iron*. It is $\frac{1}{48}$ inch.

In some places, shoemakers still use a *barleycorn* as a measure of length. It is $\frac{1}{3}$ inch, the size of a grain of barley.

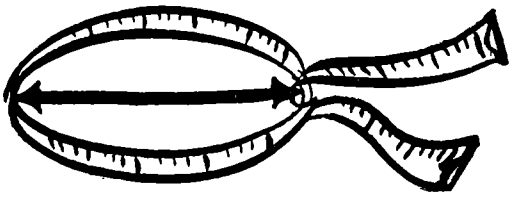
Gloves are measured by the number of inches around

the palm of your hand and your fingers, when you make your hand into a fist.

Hats

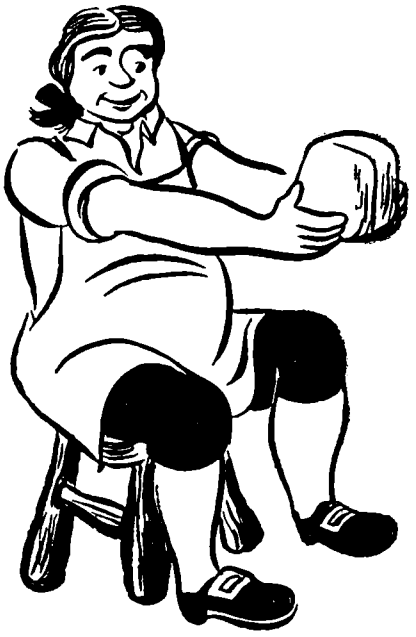
Ladies' hat sizes are very simple. They are just the measurement in inches around the head. If you wear a 22 hat, your head is 22 inches around.

Men's hat sizes are a little more complicated, but they are based on the number of inches around the head, too. This is the way it is supposed to work. You take a tape measure and measure the distance



around your head. Then you lay that tape measure down in a circle, just as it came off your head. The diameter, or distance across the circle, would be your hat size. If the circle were 22 inches around, the diameter would be 7⅛, and that would be your size.

Actually, though, it doesn't work exactly that way in the United States. The diameter of the circle on which



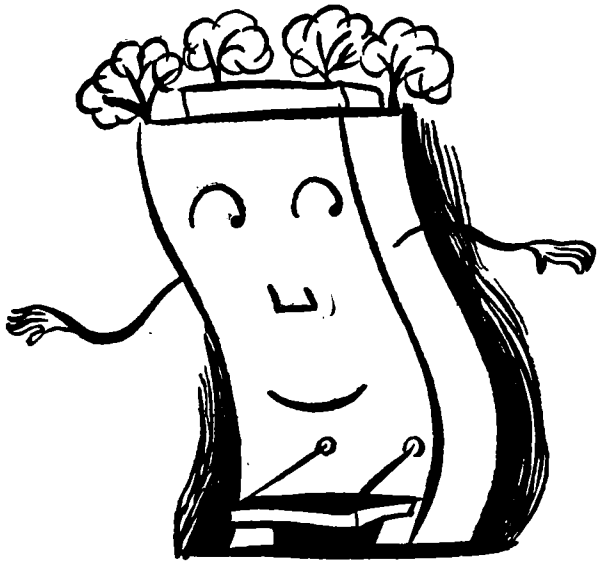
hat sizes are based is $\frac{5}{32}$ smaller than it should be. Back in the early days of this country some man who made most of the shapes on which hats were blocked couldn't figure very well. His basic form was $\frac{5}{32}$ inch off, but so many hats were made on it that people got too used to this wrong size ever to bother to change it.

BUILDING

Architects, engineers, and builders have to measure all kinds of things, from bricks to pressure, from steel to wind.

One of the most important jobs in architectural (are-ki-TECK-tyur-al) engineering is the calculation of stresses and strains. It is important to know how much strain will be put on any part of a structure and how strong it must be to resist that strain.

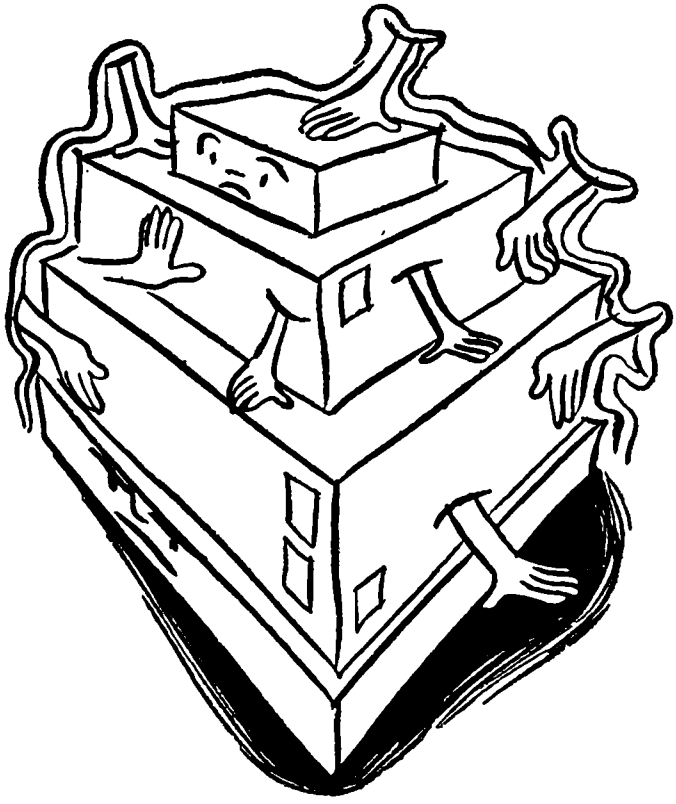
The whole building must be braced, too, to resist the pressure of the wind. Did you know that all buildings



are constructed to sway a little with the wind? If they were completely rigid, they would break. Very high ones sway as much as 3 feet.

There are many kinds of pressure on every building in the world, and the measurement of this pressure on every

square foot of a building is called *square foot pressure.* The air presses on the building, the upper floors press on the floors below, and the whole structure presses on the foundation. Every support of the building must be designed to stand this pressure.



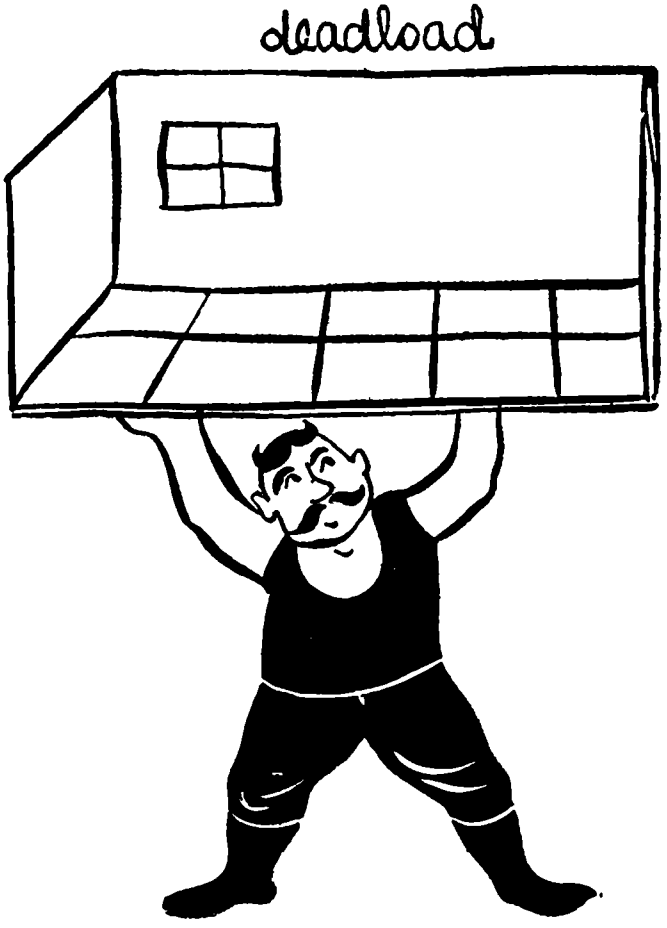
On the floor area this pressure is called *dead load* and *live load.*

Dead load is what the floor itself weighs plus the building weight it should hold.

Live load is furniture, machinery, people, and the force of moving bodies on that floor.

Dead load and live load are figured differently for

different types of buildings. A factory that is going to hold heavy industrial machinery must have a floor that will hold 300 pounds for every square foot of floor area. A factory where the machinery is not so heavy will have a floor that can hold 150 pounds for every square



foot. The live load for theaters and meeting halls, stores and showrooms is about 100 pounds per square foot, and for your house only 60.

In the old days houses used to be converted into factories without any changes being made to allow for

the increased load the floor would bear, and then the floor would collapse, taking people, machinery, and the building with it. Nowadays the rules that govern dead load and live load are so strict that this very rarely hap-

pens. Everything is actually made much stronger than it needs to be.

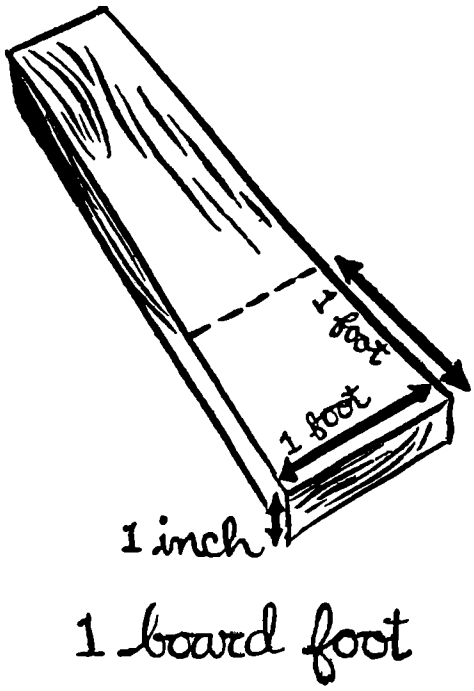
When figuring the load a roof will bear, not only the weight of the roof itself must be considered but also the weight of the rain and snow.

Building Materials

At the beginning of this book we talked about the unit of measurement for lumber, which is a *board foot.* This is just what it sounds like—a length of board 1 foot long, 1 foot wide, and 1 inch thick.

Suppose you wanted to find out the number of board feet in a board 3 inches by 4 inches and 14 feet long. You would make a fraction of these measurements like this:

$$\frac{3 \times 4}{12} \times 14$$



1 board foot

The width and thickness of 3 inches by 4 inches would cancel the 12 inches, making 1 foot, and you would see that you had 14 board feet in the plank.

A 2 by 6 board, 14 feet long would also have 14 board feet in it.

There is another lumber measure, used mostly for fancy moldings and very narrow lumber. It is called a running foot. That means you pay no attention to the width of the board or molding, and just measure its length in linear feet. That way you don't get tangled up in too many fractions.

Boards come in many different sizes, but if you ordered a certain number of board feet instead of a certain num-

ber of boards, you would know exactly how much you were getting. You pay for lumber at so much a board foot. Wood for fuel is measured by the *cord*, originally with a cord or line. A cord of wood is 8 feet long, 4 feet wide, and 4 feet high. This is a convenient size for handling and chopping, and the logs can easily be cut into the 2-foot lengths that fit most fireplaces.

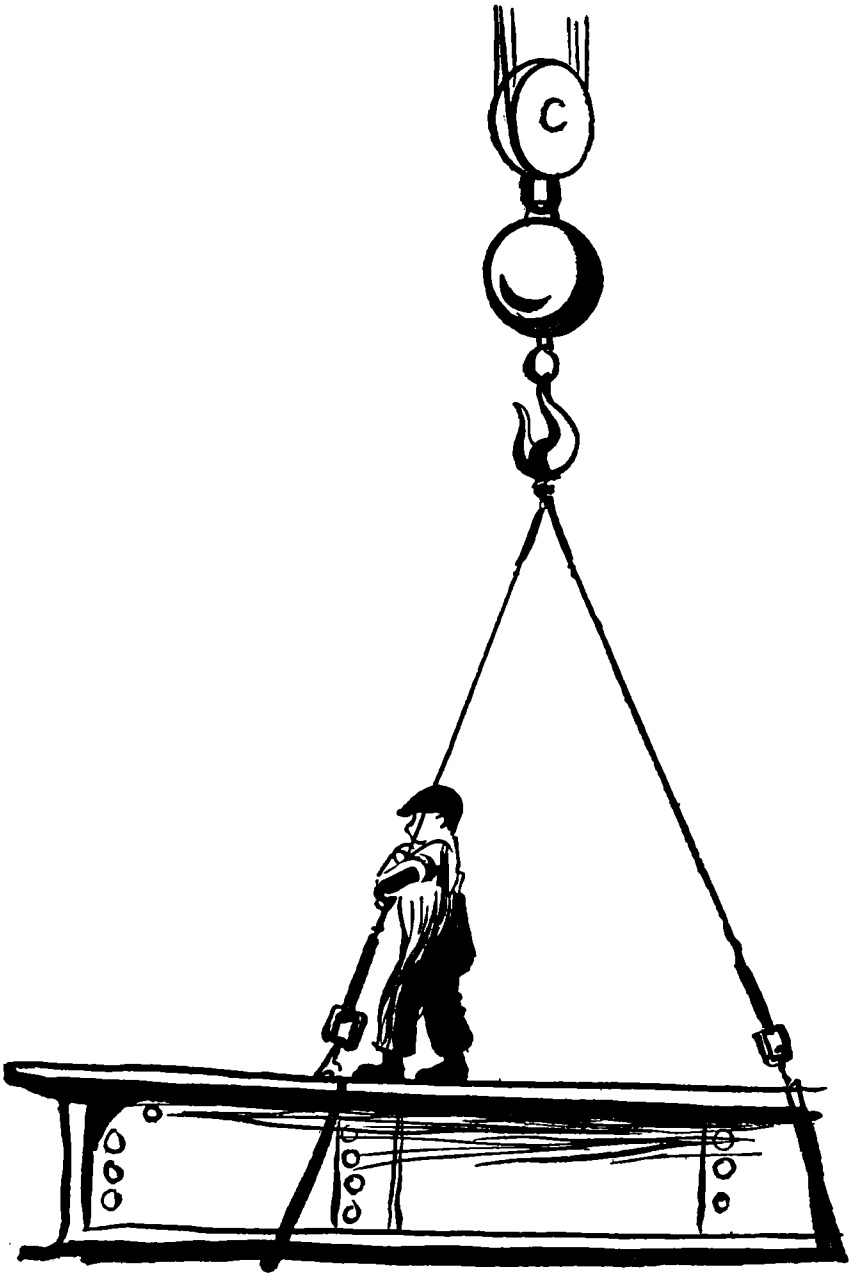
Steel is measured by the ton.

Bricks are measured by the thousand. Figuring how many bricks will be needed is called estimating, and a mason with much experience can come very close to the actual number required.

Cement can be measured either by the bag or the barrel. A *bag* of cement weighs 94 pounds net. A *barrel* of cement is 4 bags. It weighs 376 pounds. Lime comes by the barrel, too—either 180 or 280 pounds.

Pipe is measured in *inches*.

Wallpaper comes by the *roll*. There are 30 square feet in a single roll of wallpaper, so the length of the roll



depends on its width. Narrow rolls are usually 8 yards long, and wider ones 5 yards. Some rolls are double rolls (French wallpapers are usually put up in double rolls), and some are triple. English wallpaper is usually put up

in a length 1½ times that of a single roll. When the paper hanger estimates how much wallpaper he will need for a room, he measures the number of square feet

of wall surface, deducts the area of doors and windows, and divides by 30.

The thickness of wire is measured in thousandths of an inch. A thousandth of an inch is called a *mil.*

Nails come by the *keg*, and a keg of nails is 100 pounds.

PRINTING

The printing trade was among the first to use international standards of measurement.

In the eighth century the Chinese started printing from engraved wooden blocks. The first movable type was

supposed to have been invented by a Chinese wood carver named Pi, and a number of printing terms are named after him. (Most important of them is the *pica*, which is a measure equal to .166 inch or about ⅙ inch.) This was the first time pictures or writing had ever been reproduced in any way except by hand. It wasn't until the thirteenth century that people in Europe started printing from wooden blocks, too. In the fifteenth century Johannes Gutenberg invented the first movable type letters that could be used on a printing press. That was the beginning of the modern printing trade.

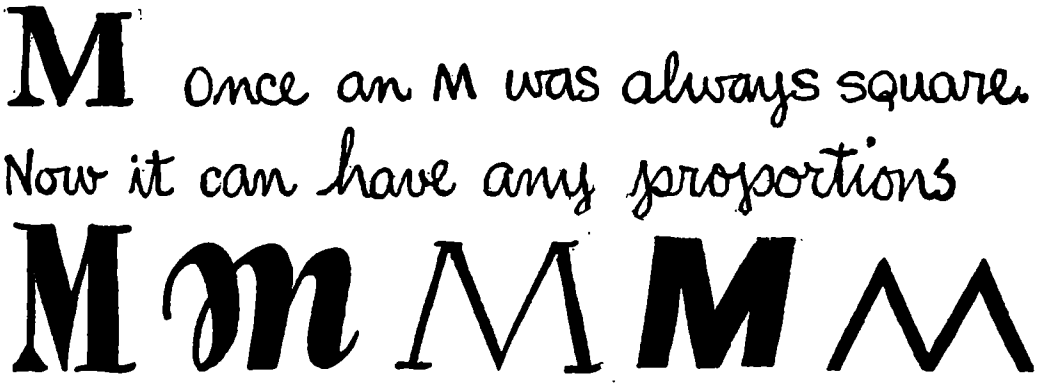
Printers' Measures

The *point* is the unit of measure for type size that is standardized all over the world. It started out as a French measure, but was picked up by printers in several countries because they needed a simple way of comparing the various sizes of types.

The system of measuring by points began by taking the pica type, which was the most common size, and dividing it into 12 parts that were called points. Since this type was approximately $\frac{1}{6}$ inch high, each point was about $\frac{1}{72}$ inch. This system of measuring applies to all types now and was adopted by the United States Type Founders Association in 1886. A great many printers were using it before it became official.

The height of the type determines the size in points. All 12-point types, for instance, will be the same height, though their widths may vary a great deal. The type in this book is 12 point.

The *em* is one of the printer's most useful standards for measuring. It is the portion of a line taken up by the letter M in whatever type he is using. The em is com-



monly used for measuring the width of a column of any size of type. An *en* is the width of the letter N and is half as wide as the em, which as a measure is always square.

A *pica* was originally just a special size of type 12 points high. Since a point is $\frac{1}{72}$ inch, a 12-point letter is $\frac{1}{6}$ inch high and that is the measurement of a pica. It is the most common measure used for figuring the widths of columns of type, which are always given in picas. Printers, book designers, writers and other people who work with type have special rulers called pica rules. These have inches divided into $\frac{1}{6}$ths.

A *nonpareil* (non-pah-RELL) is 6 points, or $\frac{1}{12}$ inch.

Leading is the space between lines of type. It is actually the thin strips of some type-metal that are used to separate

the lines. Leads vary in thickness from ½ point, which is 1/144 inch, to 3 points, which is 1/24 inch. The most common is the 2-point lead. If there is much leading between the lines of print, quite a few strips of metal separate those lines. The leading in this book is 3 points. The printer would say that the book is set in "twelve on fifteen," which means that it is a 12-point type set in a space 15 points deep.

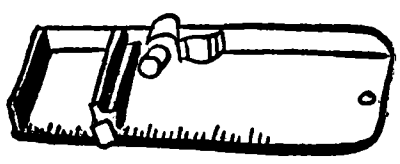
Type size is figured in points, but in addition to the height of the letter on the page, the width of the type has much to do with the size it seems to be. According to its width the type can be

standard
condensed
extra-condensed
extended

The *weight* of a type is reckoned by the thickness of the lines that make up the letters themselves. In weight a type can be

lightface
medium
boldface
extrabold

A *stick* of copy is really not a measurement of an amount of copy but a composing stick, or narrow metal tray, in which the type is set. Usually, though, it denotes the amount of type that can be set in that tray.



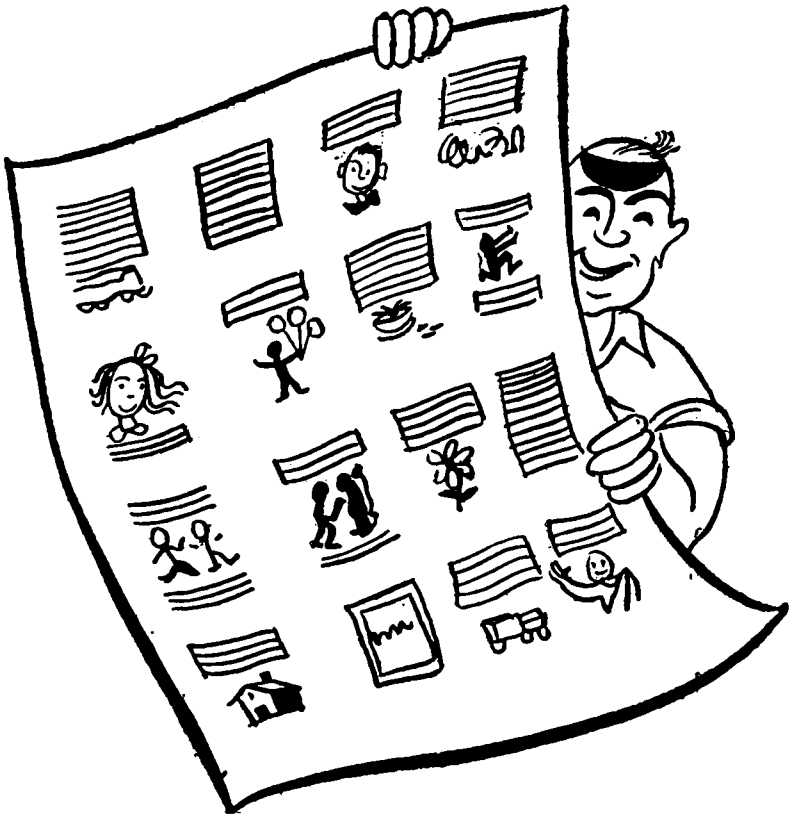
A *slug* of type is a line of type cast in one piece.

A *ream* is 500 sheets of paper, and a *quire* is 24, or sometimes 25, sheets.

A *pound* is the unit of measurement of the weight of paper. A printer may buy 10,000 pounds of 60-pound paper. Sixty pounds would be the weight of 500 sheets of a certain size of paper.

There are different kinds of 60- or 80- or 90-pound papers, too. Papers to be used for pages of a book may be entirely different from paper to be used for a cover, though they are both 60-pound papers. If you ask a printer to explain to you how this strength in pounds is

a lot of different pages are printed on one big sheet.



figured, he will probably cover whole sheets of paper with figures and then say that it takes a book really to explain it.

Ink is bought by the pound, too, but just by plain weight.

A *signature* is a section of a finished book that is folded and bound with other signatures to make the whole book. If you look at the top of this book you will see several signatures bound together. Each one is really just one big printed sheet folded and cut into smaller pages.

SCIENCE

ELECTRICITY, LIGHT AND HEAT, RADIO, AND MECHANICS

Most of our modern sciences depend on measurement, because until a thing is measured, it can seldom be completely understood. Scientists have done some wonderful measuring. They know the exact distances of planets that are billions of miles away and the exact size of an electron, which is millions of times too small to be seen. They know how hot color is and how fast light travels. As science grows, better ways of measuring the old things must be found, as well as new ways of measuring things that have never been measured before.

A hundred years ago, people thought their ways of measuring were fairly exact. They were building railroads and steamships and dams and machinery that needed exactness to $\frac{1}{100}$ inch. Now scientists can measure in millionths of an inch. They can weigh things that have practically no mass and measure the speed of invisible particles traveling as fast as light itself.

The ordinary standards of length, mass, and volume are not enough to meet the needs of measuring for modern science. Electricity, light, heat, time, and many other things that can't be held or weighed or touched must be measured, too. Scientists have had to figure out standard units for every force with which men work.

Here are some of the standards science uses.

ELECTRICITY

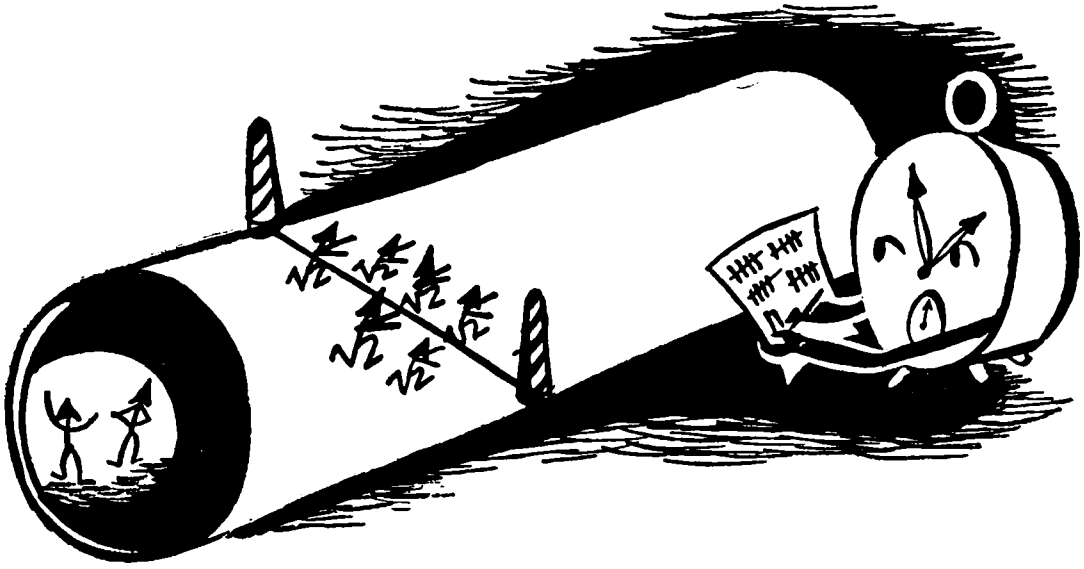
An *ampere* is the measurement of the flow of electric current. Just as a certain number of gallons of water will flow through a pipe in a certain time, a definite number of amperes of electric current will flow through a wire.

Amperes were named after a French scientist, André Ampère.

When electric current pushes through a wire, there are other electric particles in the wire that try to keep it from flowing. That pushing against the current is called resistance, and is measured in *ohms*. Ohms were named after G. S. Ohm, a German electrician.

A *volt* is the measurement of the amount of electric pressure needed to drive 1 ampere through a resistance of 1 ohm. Volts push amperes through the wire. The volt was named after an Italian scientist, Alessandro Volta.

A *watt* is the measurement of electric power needed to keep an electric current flowing. On your electric meter electricity is measured in *kilowatts*, which means thousands of watts. Watts were named after James Watt, who invented the steam engine. Volts times amperes equal watts.



The amount of electricity that passes a point in a conductor in a certain time is measured in coulombs.

A *coulomb* (koo-LOM) is the unit of measure of the amount of electricity that passes a point in a conductor (which is what an electric wire is) in a certain time. The coulomb was named after a French physicist, Charles A. de Coulomb.

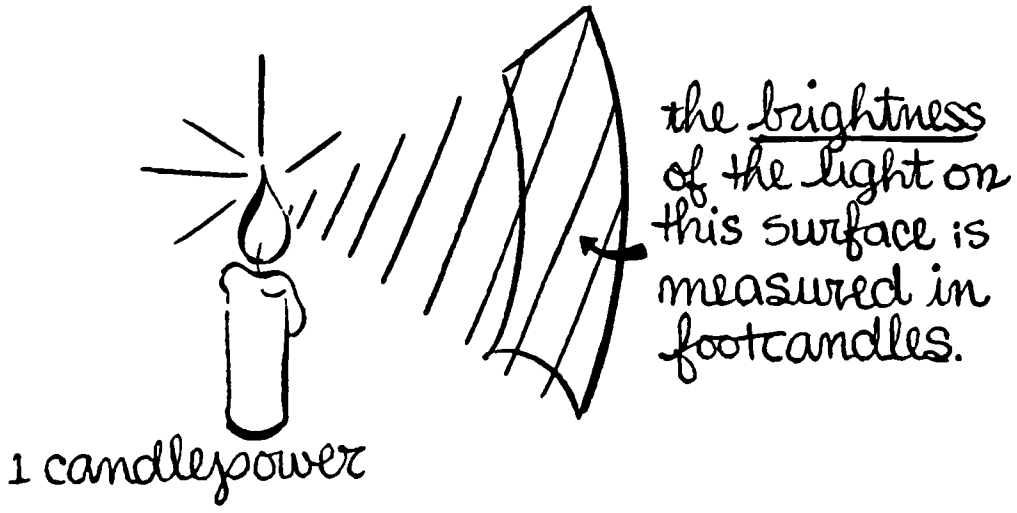
A *farad* is a unit of capacity in electricity—of how much stored electricity anything will hold. It gets its

name from Michael Faraday, who built the first electric generator.

Light and Heat

An *angstrom* is a unit of length used in measuring wave lengths of light or electricity. An angstrom is one of the smallest measurements we have. It is $\frac{1}{250}$ millionth of an inch.

A *candle power* is the standard measurement of light. It is the light given off by the flame of a candle of a


the brightness of the light on this surface is measured in footcandles.
1 candlepower
The shaded area is the amount of light on the surface. It is measured in lumens.

definite size, shape, type of tallow, and wick. This standard candle was set by international agreement. The brightness of all electric lights is measured in candle power.

A *foot-candle* is the measurement of the brightness of

light on a surface one foot away from a light of one candle power. The unit of measurement for the amount of light falling on the surface is called a *lumen.*

A *degree Kelvin* is a measure of the temperature of color. It sounds odd for color to have a temperature, but color, which is a form of light, is a form of heat, too. If you've ever seen a piece of very hot metal, you know how color and light and heat are related. As the metal gets hotter, first it glows red, and then, when it gets still hotter, it glows white. The Kelvin temperature changes with the color. On the Kelvin temperature scale, zero is at −273 degrees centigrade, or −523.4 degrees Fahrenheit, two ways of measuring heat that we will talk about in the section on the weather. The temperature of the sunlight in the middle of the day is about 6000 degrees Kelvin.

A *light-year* is the distance over which light can travel in one year. Since light travels at a tremendous speed—186,000 miles a second—a light-year is an enormous distance. It is 6,000 billion miles. Light-years are used to measure the distances between the stars, the sun, and the planets. Most of the stars are more than 100 light-years from the earth.

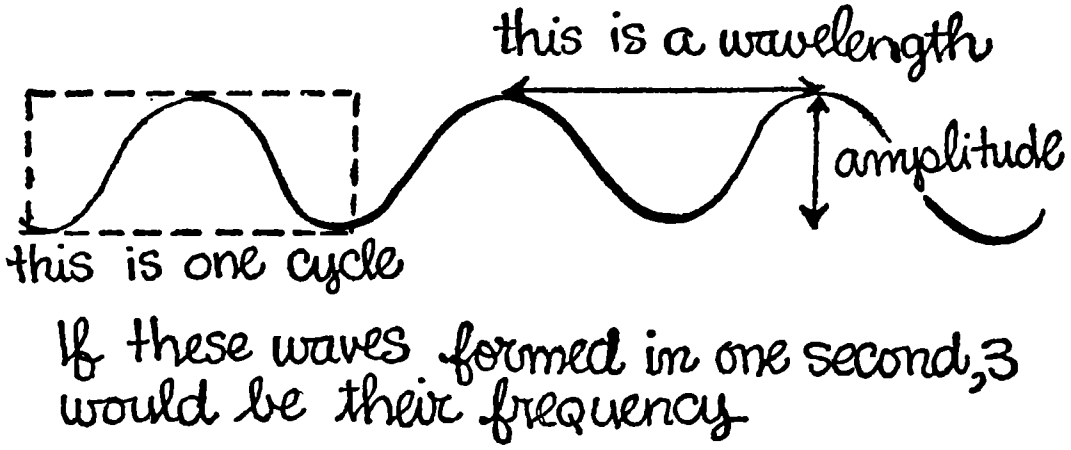
A *calorie* is the unit of measurement for heat. To a scientist it is the amount of heat necessary to raise the temperature of 1 gram (or sometimes 1 kilogram) of water 1 degree centigrade.

We usually think of a calorie as an amount of energy released by the food we eat. When somebody says, "I

mustn't eat any more calories today," he is *really* saying, "I mustn't eat any more horsepower." If he eats more calories than he uses, his body stores that energy as fat.

Radio

A *cycle* is one complete movement of an electric wave. Radio waves are measured in cycles or, because they move so fast, in kilocycles (thousand cycles) or megacycles (million cycles) a second.



Frequency is the measurement of the number of cycles of waves that form and move outward in a second. When you hear a radio announcer say that his station is operating on a frequency of so many kilocycles, he means that it is broadcasting that many thousand radio waves a second.

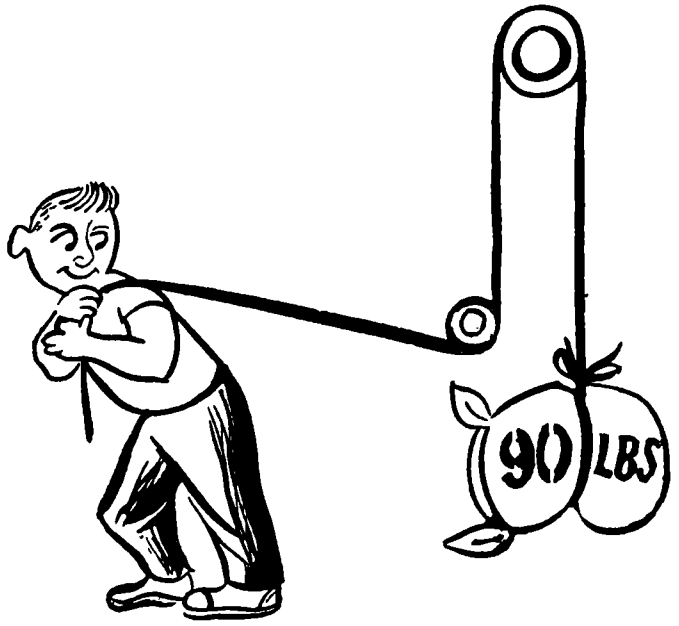
The loudness of sound—in radio or anywhere else—is measured in *decibels*.

Mechanics

A *foot-pound* is a unit of energy. Energy is the ability to do work. A foot-pound is the energy needed to raise a weight of 1 pound to a height of 1 foot.

Horsepower is a measurement of energy, too. By making a great many tests James Watt figured out that the average horse could lift a weight of 550 pounds 1 foot off the ground in 1 second. So it was agreed that an engine with this same power would be a 1-horsepower engine. A 30-horsepower engine has the power of 30 horses.

Another measurement of energy is *man power*. The average man can lift a weight of 90 pounds 1 foot in 1 second, and that energy is called 1 man power.



1 manpower

Tensile strength is the measurement of the greatest strain any material can bear without breaking, so it is an important thing to be able to measure. It is usually figured in the number of pounds of pressure per square inch that are necessary to make the material tear or break.

All kinds of materials are tested for tensile strength before they are used. Steel for buildings is tested, and so is paper, and also silk or rayon for stockings. Cookie

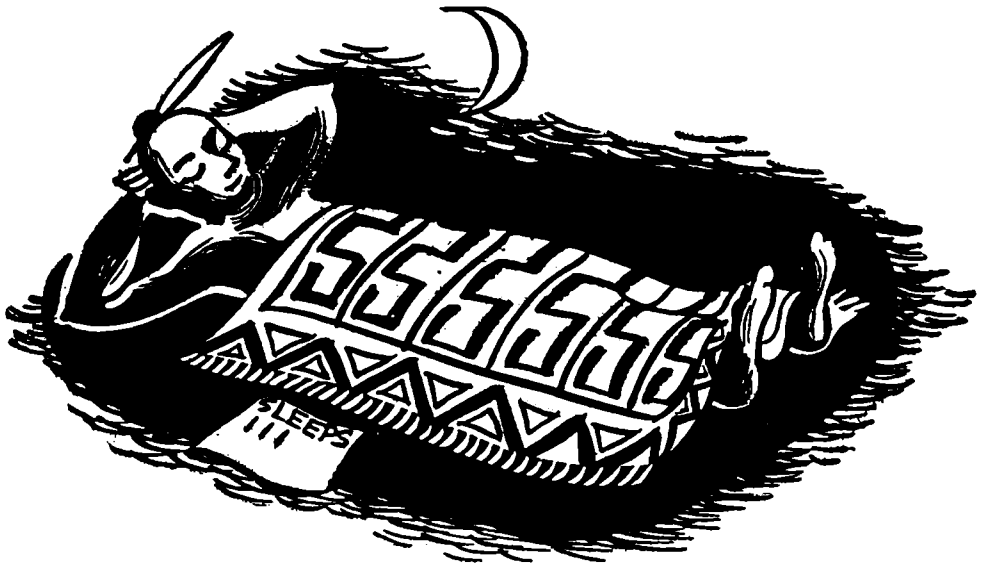
A bar is pressed down on the cookie until it breaks.

manufacturers even test the tensile strength of their cookies! If the cookie breaks easily, the dough is tender. If it takes a lot of force to break it, watch out for your digestion!

TIME

It has always been important to have a way of measuring time, but time is not something that can be held in a container or lifted onto a scale or measured with a stick. The only way to measure time generally is to record the repetitions of regular events.

From the beginning men had crude ways of figuring the passage of time. From sunrise to sunrise was a period that could be counted, or from full moon to full moon, or from one spring flowering to another. Every repetition of familiar things was a way of reckoning time. The Indians counted years by "winters" or "summers," months by "moons," and days by "sleeps."



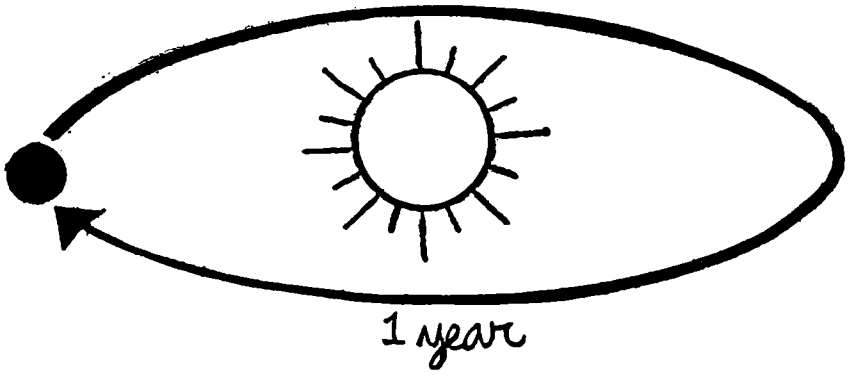
But these reckonings were not exact. The hours of light between dawn and dark varied greatly during a year. Spring flowering came early one year and late the

next. The only period of time that didn't vary was that from full moon to full moon. People soon learned that the most exact way of measuring time was to use the heavenly bodies as measures.

The most practical standard for keeping time is the rotation of the earth, so this rotation is our main timekeeper.

The Year

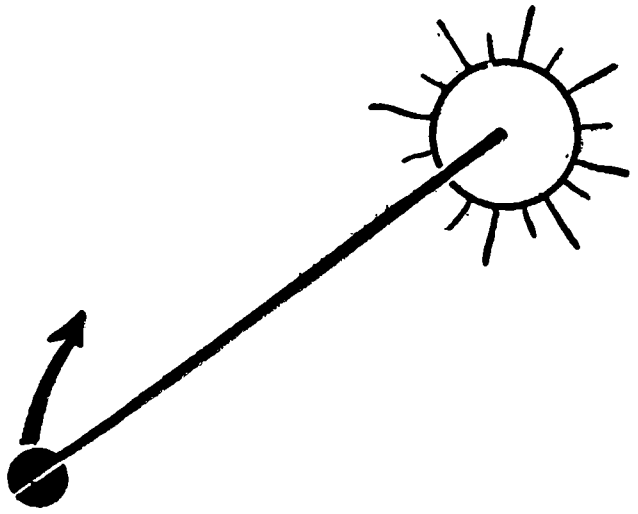
Our *year* is the period of time it takes the earth to make its revolution around the sun. There are several ways of reckoning a year, all slightly different.



The *sidereal* (sy-DEER-ee-al) *year*—the name means that it is determined by the positions of the stars—is the most exact, but also the most complicated to figure. So we use a more convenient way of measuring a year. The pictures will help you to see how it works.

We start at the time when the sun's center crosses an imaginary line drawn straight out into space from the equator. If you live in the northern hemisphere, the sun

is traveling north, toward you. When the sun crosses this imaginary line, day and night all over the world are equal. Scientists call this moment the vernal equinox (EE-kwi-nox), and we call it the beginning of spring. When this same thing happens again, a year has passed. The sun crosses this line again in the fall, and day and



night are equal, but it is traveling in the other direction. That crossing is called the autumnal (aw-TUM-nal) equinox.

In olden times people actually started their year about the time of the spring equinox, when everything burst into bloom. It wasn't until the beginning of the seventeenth century that they started reckoning the new year from January 1.

Sometimes our year is called the astronomical, or equinoctial (ee-kwi-NOCK-shal), or natural, or solar year, but scientists usually call it the *tropical year*. It is 365

days, 5 hours, 48 minutes, and 45.7 seconds long. Those extra hours and minutes are lumped together every four years to make the additional day we have in *leap year*.

Ten years are called a *decade*, 100 years a *century*, and 1000 years a *millenium*.

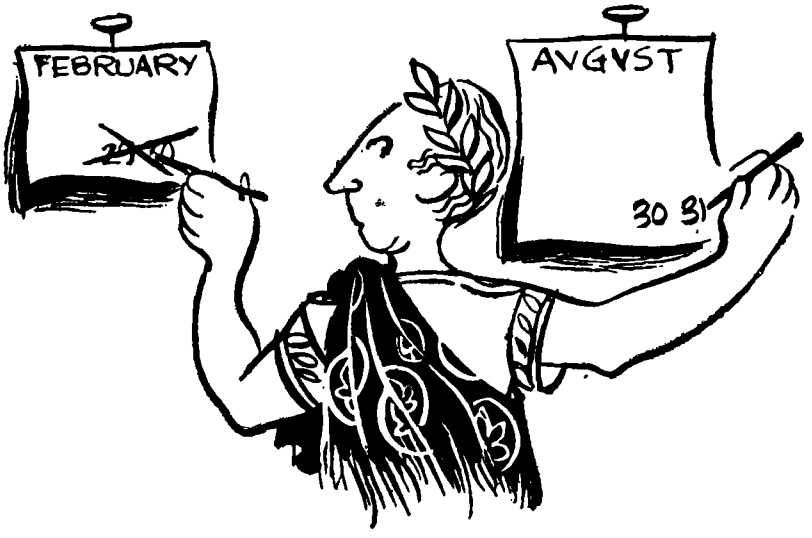
The Month

A *month* was the earliest accurate division of time because it was figured from new moon to new moon—just 29½ days. This period is called a *lunar month*, and at

first a year was divided into 12 lunar months. Then the trouble started, because figuring just 12 lunar months to a year leaves 11 days over when the year is calculated by the earth's rotation around the sun. If those 11 days were used to start a new month, soon the year would be all mixed up, with no regular events governing it at all.

So, since the lunar month fixed by the moon and the year fixed by the sun have no relation to each other, one had to be abandoned.

In the year 46 B.C. Julius Caesar abolished the use of the lunar year of 12 equal months and fixed the *solar year* of 365 days with an extra day every four years.



The 12 months were based roughly on the lunar months, but were of unequal lengths. As a matter of fact, the different Caesars used to subtract days from some months and add them to their favorite ones.

The Week

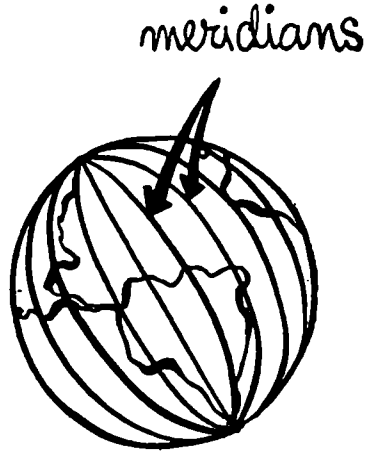
The *week* of seven days has no real connection with any movement of heavenly bodies, although the four weeks in a month might have started as divisions that represented the four quarters of the moon. Two weeks are called a *fortnight*, short for 14 nights.

The seven days were probably named after the seven

planets that were known to the ancient world, because almost everywhere on earth they have the same names. These planets, in turn, were named after the important gods of the ancient world. Sunday is the sun's day, Monday is the moon's day, Tuesday is Mars' day (the Saxons called Mars Tiw), Wednesday is Woden's day, which was the Saxon name for Jupiter. Thursday is Thor's day. (The Romans called Thor Jove.) Friday was dedicated to Venus, whom the Saxons called Frigg. And Saturday is Saturn's day. As you can see, we used the Saxon, or English, names instead of the Latin ones.

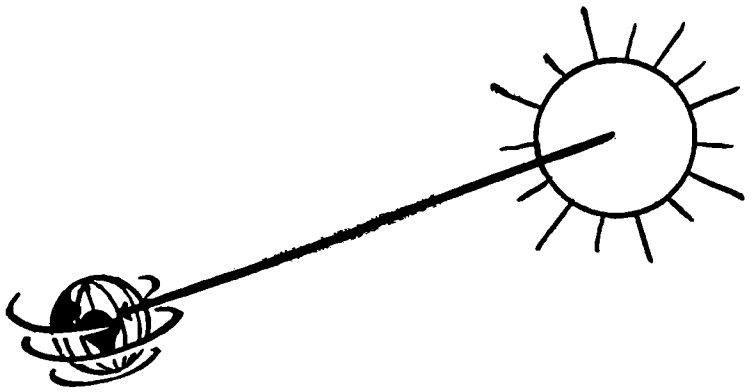
The Days

The length of a *day* is fixed by the period of the earth's rotation on its axis. As the earth turns, the sun crosses each meridian. (The meridians are imaginary lines drawn from pole to pole to divide the earth's surface.) When it crosses any particular meridian again, a *solar day* has passed.



At different times of the year days appear to be of different lengths because the positions of the earth and the sun are changing. So to make timekeeping easier we imagine a sun that always moves in the same path, midway between the points where the days are longest and shortest, and we reckon our day on that. We call this the *mean solar day*. "Mean" means "average."

The time when the "mean sun" crosses the meridian at any point on the earth is mean noon at that place. This would make the time differ every few miles, so by international agreement the earth has been divided into 24 *time zones*. Zones next to each other have a time difference of 1 hour.



As the earth spins, each meridian passes across the sun's center.

A new day begins when it is midnight at any particular place. This new day starts first at a place in the Pacific Ocean, halfway around the world from the meridian at Greenwich, England (which is called the *prime meridian*).

The place where the new day starts is called the *International Date Line*. When Monday starts at the International Date Line, it is still Sunday in the rest of the world.

In ancient times days were reckoned from dawn to dawn in some places, from dusk to dusk in others. Now a new day starts at midnight everywhere except on ships

at sea. Aboard ship the day starts at noon and is divided into six *watches* of 4 hours each. Bells tell the sailors what time it is—one bell for the first half hour of the watch all the way up to eight bells for the last, and then they start over.

The Hours

An *hour* is a twenty-fourth part of the mean solar day. Hours are just a convenient way of dividing the day. There is no natural division of time, no repetition of anything that makes an hour the length it is.

For convenience, we divide a day into 12-hour halves. We call the half before noon, when the sun crosses the meridian, A.M., or ante (which means "before") meridian. The second half is the P.M., or post meridian part of the day. (Post means "after.")

Sometimes people don't use A.M. and P.M. hours at all, but number the hours straight through from 1 to 24.

Military operations run on a 24-hour clock. Suppose an operation were set for 3 P.M. Through an error in transmitting or understanding orders, there might be confusion about whether the time was to be at 3 A.M. or 3 P.M. But if it were set for 15 o'clock, there wouldn't be any possibility of a mistake.

The first device men had for measuring time was the sundial. The earliest ones were just upright sticks which cast a shadow on the ground. A later sundial was a hollow half bowl with a bead fixed in the center. As the sun crossed the sky, the shadow of the bead traveled in an arc across the face of the bowl. The bowl was divided into 12 equal parts called hours. The length of these hours

varied with the seasons, as days were longer or shorter. In the summer an hour might have been half again as long as our hours now, in the winter only half as long. For 1,600 years this way of measuring hours by dividing the daylight into 12 parts didn't change.

Minutes and Seconds

A *minute* is the sixtieth part of an hour and a *second* is the sixtieth part of a minute. Both of these measurements are for convenience in dividing time into useful

sections. The ancient Babylonians started these divisions. You remember we said they divided a great many of their measures into 60 parts. These Babylonians reckoned time more accurately than the people who came after them for several thousand years. They used a water clock, the water running through a hole of a very carefully calculated size from one jar into another. The time it took for the water to drip completely through was the length of the day of the equinox. Day and night are equal at that time, each lasting 12 hours.

Clocks are among the most important measuring machines ever invented. They change time, which we can neither see nor hold, into a measurement of distance on the face of the clock where we can measure it easily.

Our modern industry depends on clocks and timing. Assembly lines run on exact time schedules. In the manufacture of almost every article around you there are certain processes that must be timed precisely. China must be baked for an exact length of time, glass hardened, paint dried electrically, canned food processed. If you look around your room, you will probably see dozens of other things that had to be timed when they were made, some of them to a millionth of a second. The manufacture of parts of radio tubes and light bulbs must be timed as exactly as this.

Our whole world runs on a time schedule. Trains and planes, schools and businesses, radios, traffic lights, and the cake for dessert all depend on the clock.

Flyers make a clock out of the sky, so they can call directions. They imagine it to be a huge clock face with

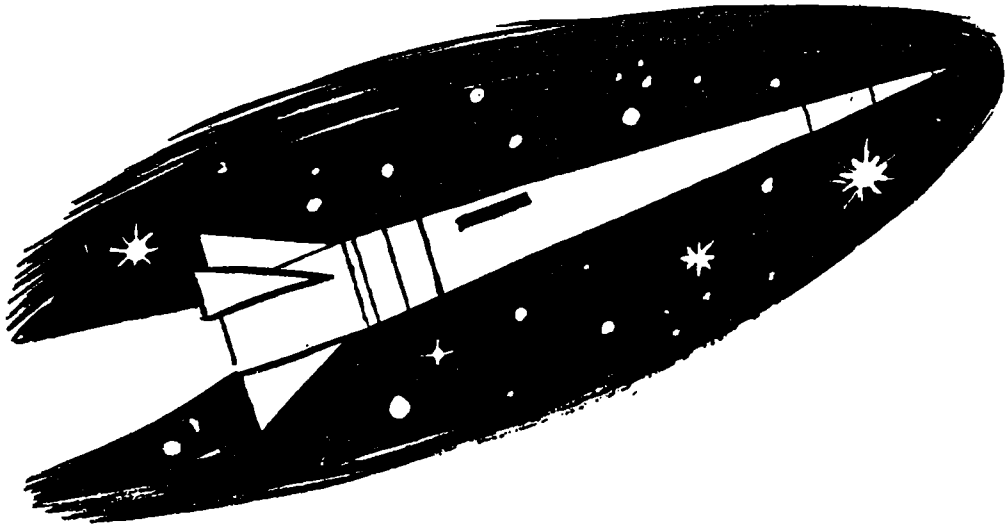
their plane at the center of the dial. The nose of the plane points to 12 o'clock. Then if one man yells, "Sea gull at 2 o'clock," everybody knows exactly where to look.

People have always thought that time was *constant*, that it never changed: that a year was a year, that a second for one man was exactly like a second for another, no matter what. Part of Mr. Einstein's Theory of Relativity says that this is not true. It says that when something is going very, very fast, approaching the speed of light, time for that thing slows down.

If this is true, and if someday men can build rockets that travel fast enough, it will make a big difference in our travels through space. Years on earth would be only weeks or months to the travellers in the rocket. There would be time to travel to the stars.

SPACE TRAVEL

Everything about space is bigger or faster or hotter or colder or farther than the things around us on earth. Space itself is so immense we can't really imagine it. Some stars are so far away that their light does not reach us for billions of years. There are so many stars that we haven't yet found a way to count them. Some people say there



are *countless* stars. This means that they are uncountable only because we have never found a way to count them all. Some people say the number of stars is *infinite*. This would mean that they go on forever, without end. You cannot count an infinite number of anything.

Scientists who work with such enormous numbers have to use special ways of counting and figuring or the numbers would run off the page. To help them with such big numbers they use a special kind of little number called

an *exponent*. An exponent stands for the zeros in a big number. It stands for the number of times that number is multiplied by 10, or by itself.

If you want to write ten billion, instead of writing 10,000,000,000 you can write 10^{10}. If you multiply ten billion by another number you can write it like this: 7×10^{10}. Otherwise, it will look like this: 70,000,000,000.

Distances in space are measured in *light years*. A light year is the distance light—which travels 186,000 miles a second—travels in a year. That distance is six million million miles. Some distances in space are measured in billions of light years.

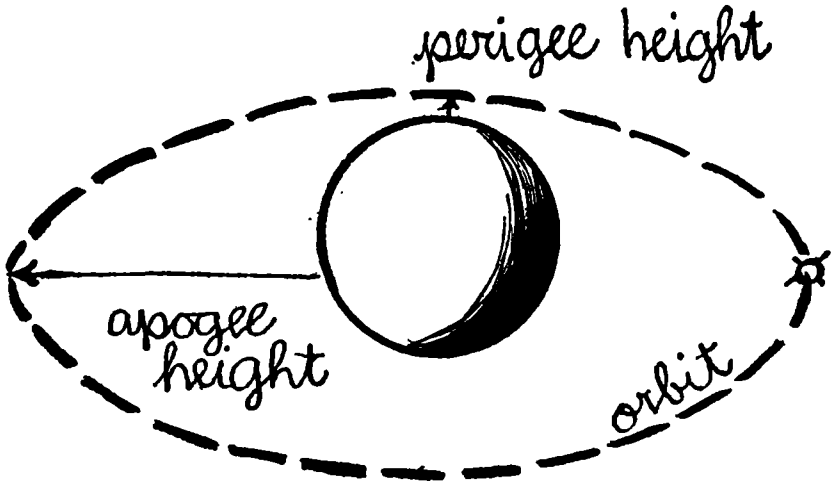
Space scientists have to figure many kinds of things besides distance. Usually they have machines to help them—computers, testing devices, radar, radio telescopes and more. Here are some of the things they have to measure.

They have to measure the force of gravity. Gravity is the pull of the earth on everything on it and around it. The force of gravity is written as *g*. At the earth's surface there is a pull of 1*g* on you. This is equal to your weight. Starting up in a rocket, or coming back to earth, the *g* force increases. If there is a pull of 2*g* on you, your weight doubles. If you ordinarily weigh 100 pounds, at 2*g* you weigh 200, at 5*g* you weigh 500.

The power of the motors that drive the rocket is called *thrust*. Thrust is measured in pounds. Small rockets have a thrust of thousands of pounds. Big ones have a thrust of hundreds of thousands of pounds.

The speed that is needed to escape from the earth's gravity is called *escape velocity*. (Velocity means "speed.") Escape velocity is 25,000 miles an hour.

A satellite or rocket in orbit is not always the same distance from earth. The orbit is the path it travels around earth. The orbit's farthest point from earth is the *apogee height*. The point closest to earth is the *perigee height*. These distances are measured in miles. The length



of time it takes a satellite to complete its orbit is its *period*. The period is measured in minutes.

Scientists call the cycle of light and darkness the *diurnal cycle*. We call it day and night. In a space ship orbiting the earth, day and night are meaningless, because light and darkness follow each other in minutes. Spacemen in orbit will have to make up a night and day schedule of their own so they will sleep and eat regularly. Space medicine experts figure on "days" and "nights" of six or eight hours.

In space, the radiation from the sun is immense. Some of this radiation is in the form of cosmic-ray particles, bits of atoms travelling at almost the speed of light. Their energy is measured in *electron volts*. Radiations of cosmic-ray particles are from 100 million to 10 billion electron volts.

Radiation is measured in *curies*. Curies were named for Marie and Pierre Curie, who first discovered radiation. Exposure to radiation is figured in *roentgens* per hour. (Roentgen was the man who discovered X-rays.) A human being could take an exposure of 0.2 or 0.3 roentgens for several weeks without being harmed. But in some parts of space, instruments have monitored 10 roentgens. Anyone exposed to this much radiation could not live more than a day or two.

NAVIGATION

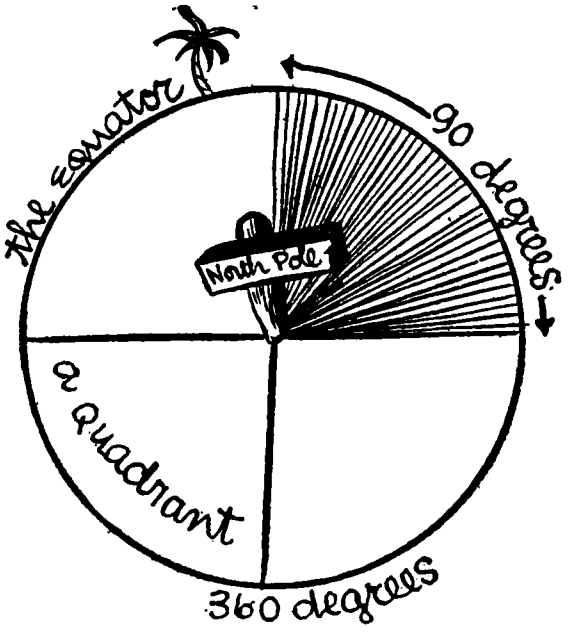
Navigators have a special kind of measure all their own called *circular measure*. This measure is based on the circle of the earth, but you can see how it works from any circle. A circle, to make figuring easier, can be divided into 360 parts called *degrees*. These degrees are like 360 thin wedges in a pie.

This system of cutting a circle into degrees is one of the oldest in the world. The Babylonians used it first. Since they reckoned the year as 360 days, and the year is a circle of the seasons, and of the stars, they divided circles into 360 parts, too.

Dividing the Earth

For dividing the earth navigators use the circle of the equator. First they divide the circle into four parts called

quadrants, which cut the earth into four quarters. There are 90 degrees in each quadrant.

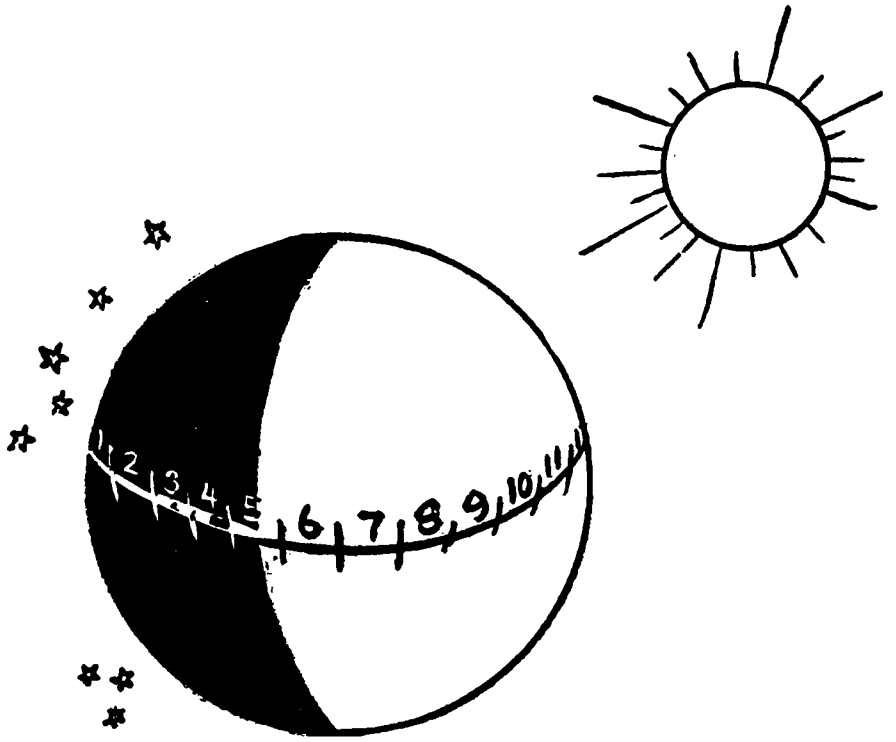


Now a degree itself is a fairly big thing, as far as distance around the earth goes, so each degree is divided again into 60 parts called *minutes*. Then each minute is divided into 60 *seconds*. These are minutes and seconds of *distance*. They are different from minutes and seconds of ordinary time. Seconds are very small wedges in the pie of the earth's circle. The Babylonians figured out all these measurements, and in thousands of years they haven't changed at all.

Time and Distance

Degrees, minutes, and seconds are measurements of distance, but they are related to time, too. The 360-degree circle around the earth at the equator can be divided by the number of hours in the day, because the earth turns the full 360 degrees every 24 hours. The earth turns

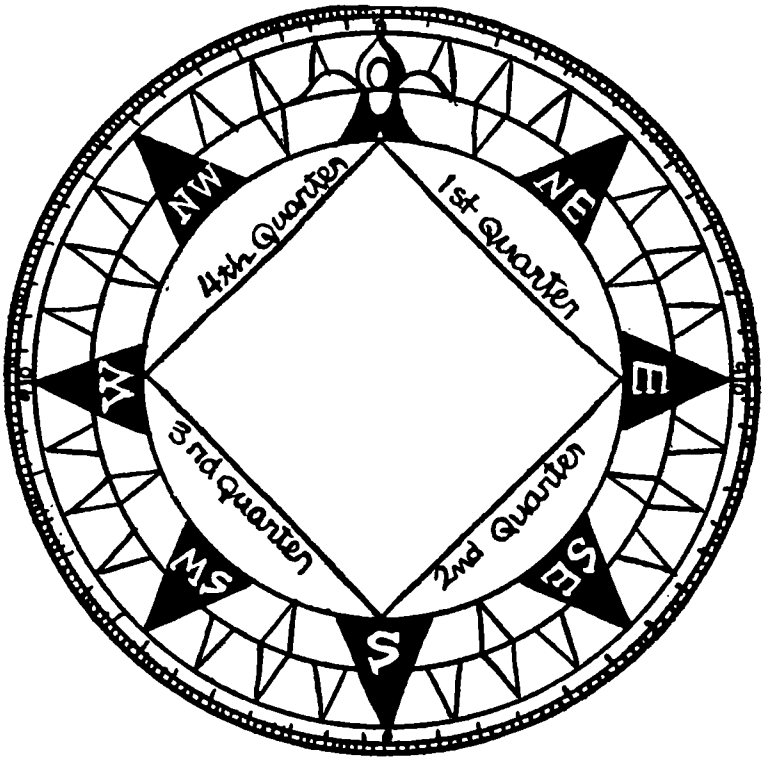
15 degrees every hour, 1 degree of distance every 4 minutes of time.



Every minute of distance around the circle is equal to one *nautical mile*, which is slightly more than one regular land mile. (One nautical mile equals 1.1515 statute or land miles.)

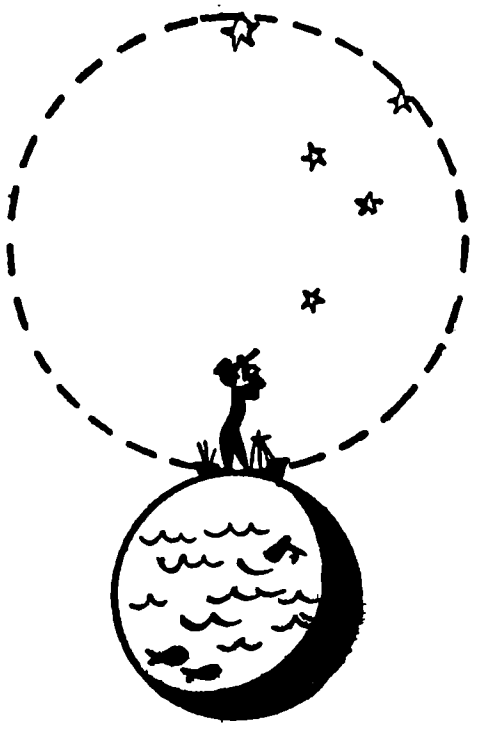
When a mariner wants to figure out where he is, the first thing he must know is the correct Greenwich mean time. He must either have a chronometer (croh-NOM-eh-ter), which is a special clock that always gives the correct Greenwich mean time

no matter where it is, or he must get that time by wireless. Then, if it is night, he measures the position of the stars over his head through an instrument called a sextant, part of which is a circular scale. (If it is daytime, he uses the position of the sun.) The position of those stars at that exact time tells him just where he is on the earth's circle. His compass has a circle on its face divided into degrees. The whole card swings so that a fixed pointer always points to north. From that he can tell the exact direction the ship is heading, and the position of lights or landmarks.



A navigator stands at the meeting point of two circles—one is the circle of the heavens over his head and the other of the earth under his ship. He needs them both in his reckoning.

Nautical Measurements



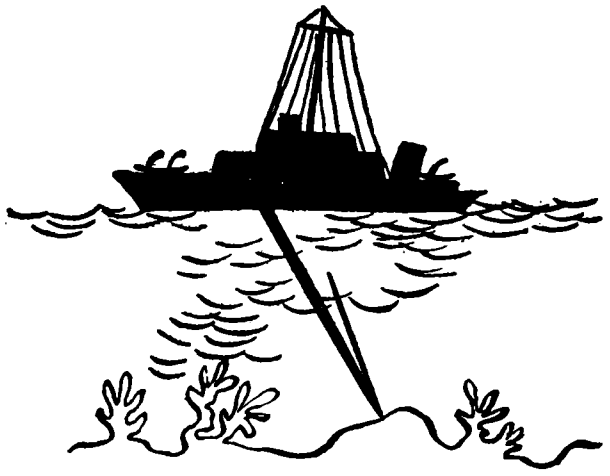
Before they had instruments to help them, very few sailors dared to sail out of sight of land for more than a few hours. No matter how far they were going, they tried to keep close to the coast line or to any islands. If the compass hadn't been invented in the fourteenth century, Columbus could never have come in search of the Indies.

But even then, and long before, sailors had ways of measuring depth of water, speed and distance. Some of these measures are still used today.

One of the early measurements was a *fathom*. A fathom was 6 feet, the length to which a man could extend his

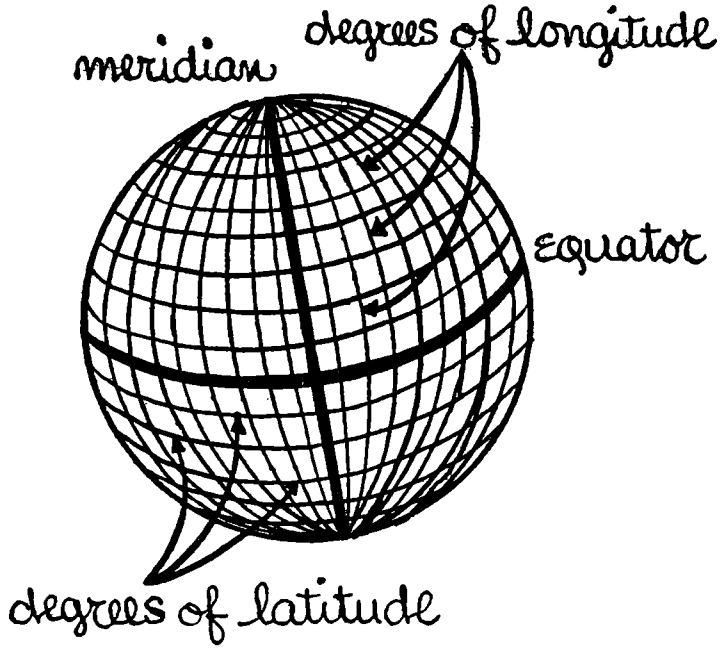
arms. This was an easy way to measure the cord or cable that was used to take depth soundings. If a sailor had measured off 6 fathoms of cord before it hit bottom in the water alongside the ship, he knew that the water was 36 feet deep.

Now, sailors use machines that send out sound waves to measure depth. The time between the instant the sound leaves the bottom of the ship and the instant it returns after it has bounced off the bottom of the sea is recorded and automatically changed into fathoms. The machine that does all this is called a fathometer. The fathometer works all the time, continually recording the depth of the water through which the ship is passing.



One hundred fathoms make a *cable's length*, which is about 600 feet, the length of a ship's cable. In the United States Navy, though, a cable is 720 feet, or 120 fathoms. Ten cable's lengths equal one nautical mile, which is 6076.097 feet. Sixty nautical miles equal one degree at the equator.

We've already said that degrees are the wedges into which navigators and geographers cut the earth so they can figure distances more conveniently. There are two kinds of degrees, degrees of *latitude* and degrees of *longitude*. The picture will show you how these degrees are measured

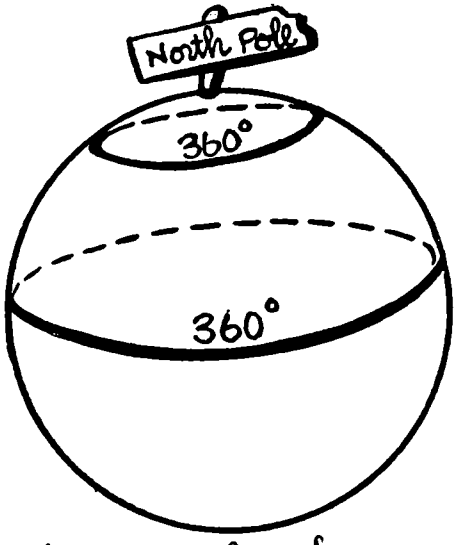


Degrees of latitude are measured along the *meridians*, the circles drawn around the earth from pole to pole, the way you would segment an orange.

Degrees of longitude are measured along the *parallels*, which are drawn around the earth, like flat slices you would make in an apple.

The circles made by the meridians around the earth are all equal. But the circles made by the parallels get smaller as they get closer to the poles. So degrees of latitude are about equal everywhere, but the number of

miles in a degree of longitude gets less as you get closer to the poles.



These two circles have the same number of degrees, so you can see that degrees in the smaller one are smaller too.

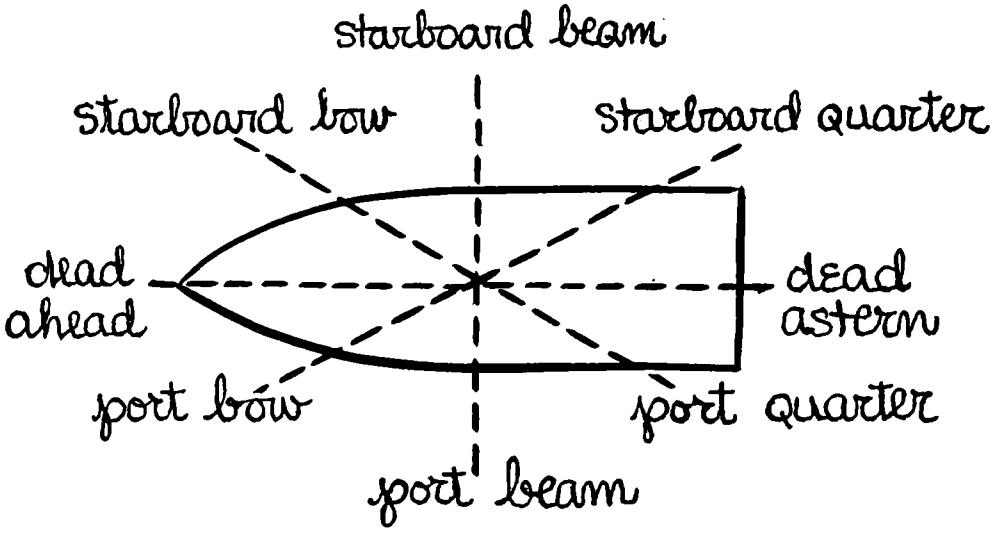
A *knot* is the unit of speed at which ships travel, and one knot is equal to one nautical mile an hour. If a ship is traveling at 20 knots, it is going 20 nautical miles an hour. You will never hear a real sailor say "twenty knots an hour," because that would be like saying "twenty nautical miles an hour an hour."

Originally each knot was a division in a special line called the ship's *log line*. This line was tied to a little log that kept it afloat when it was thrown overboard. At intervals the line was knotted, and the knots were in the same proportion to a mile that 28 seconds are to an

hour, so they would be about 47 feet apart. The number of knots that ran off a reel of line in 28 seconds was the number of nautical miles the ship was traveling in an hour. Nowadays instruments tell the speed of the ship.

Sailors use their ship as the center of the circle of the horizon, and they have a special way of dividing the ship so that it is a convenient pointer in any direction. You can see by the picture on page 124 that if the lookout shouts, "Ship off the starboard quarter!" or "Whale spouting on the port beam!" everybody knows exactly where to look.

A man named Bowditch wrote the book on navigation that most sailors use. He worked to make the rules so



simple that even the ship's cook or the cabin boy could figure out the ship's position and where it was going.

The kind of map that sailors use is called a chart. No good sailor sails into unfamiliar water without a chart, even if those waters are only a mile away from his home port. Maybe there are rocks just below the surface. Maybe there is a bridge that is too low at certain tides. Maybe the current is dangerously strong. The chart shows him all these things.

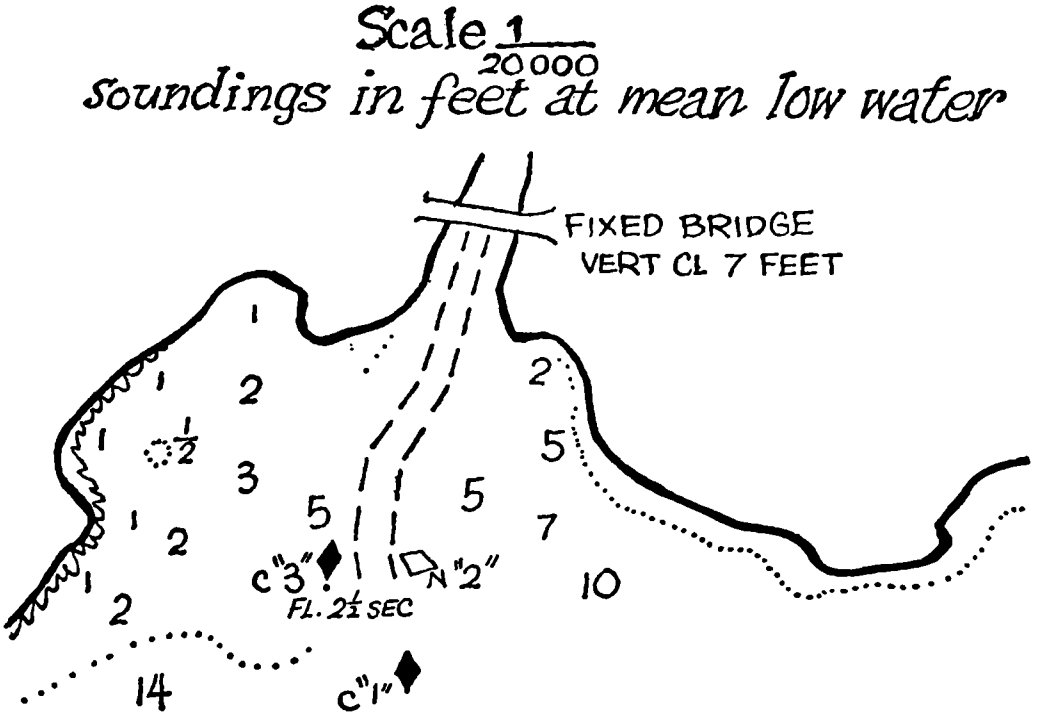
Distances on a chart are measured in nautical miles.

Depths of water are measured in feet or fathoms—the chart shows which. These depths are taken at *mean low water*, which means average low tide. This is safer than measuring the depths at high tide, because hidden rocks or bars are nearer the surface when the tide is low.

Heights of things above the surface of the water are

measured in feet at *mean high water* or high tide. If you had a boat with a 30-foot mast, and the height of a bridge was given at 28 feet, you would know that you could not pass under it at high tide, though it would be no problem at low tide. (Sailors carry tide and current tables too.)

The speed of currents (which are moving water) is measured in knots.



Buoys marking the entrance to a harbor or channel are numbered from seaward in. Number 1 is always farthest out to sea. Going into a harbor, odd numbers are always on the boat's left, or *port* side, even numbers are always on the right, or *starboard.* The safe channel is between.

The number of seconds between flashes from a light or lighthouse are shown on the chart too.

WEATHER

Long before recorded history men learned by experience to read some weather signs, but they could never tell for sure what was going to happen. (They still can't always tell for sure.)

Then, in 1593, Galileo invented the thermometer.

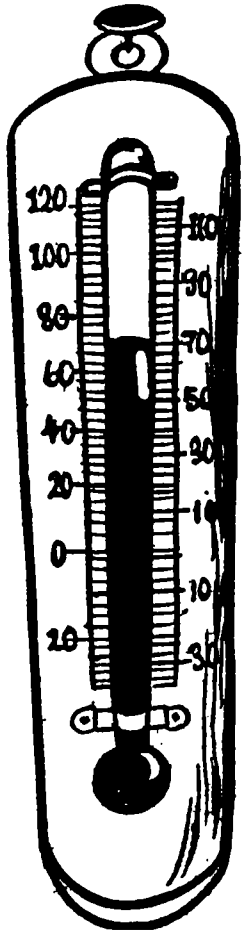
In 1643 Torricelli invented the barometer.

In 1714 Fahrenheit invented the mercury thermometer and fixed a scale of temperature.

In 1742 Celsius invented the centigrade thermometer.

After that there were ways of really measuring the weather, and here are some of those measurements.

A *degree* is a unit of heat measured on a definite scale. To be accurate this scale must be based on some physical law that never changes. The constant rate of expansion of mercury in a thermometer is the law on which most of our measurements of heat are based.



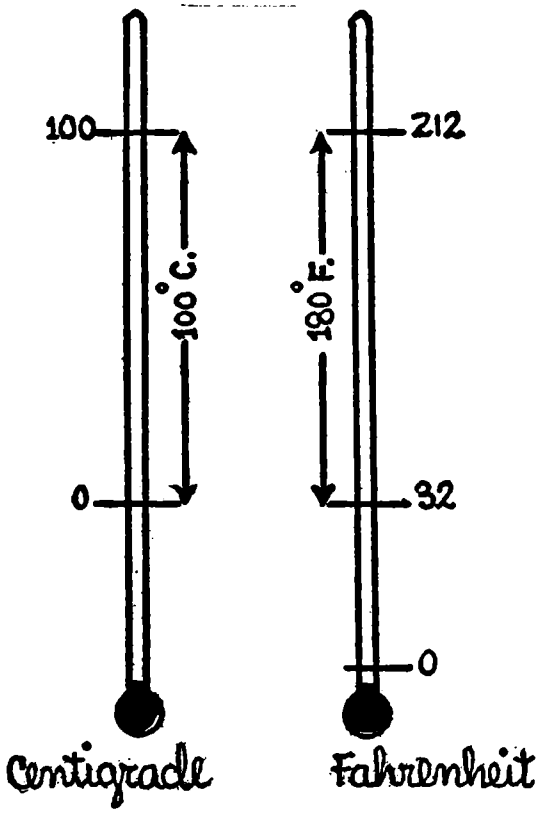
The little bulb at the bottom of the thermometer is filled with a certain amount of mercury. The warmer the air around the thermometer gets, the more the mercury expands. It goes right up the neck of the tube, which is placed against a scale of degrees. All you have to do to find the temperature is to read the number next to the place where the mercury has stopped expanding. As it grows colder, the mercury contracts, or shrinks together again, and goes down the tube.

There are several kinds of thermometer scales, but the two most commonly used are the Fahrenheit and the centigrade.

The Fahrenheit thermometer is the one we see most in everyday places. The freezing point on this thermometer—the point at which water will freeze—is 32° above zero. The boiling point of water is 212° above zero. (° is the symbol for degrees.)

The centigrade thermometer's scale is easier to figure with than the Fahrenheit scale and so it is used more for

scientific measurements. Centigrade means "hundred steps." On this thermometer freezing is at 0°, and boiling is at 100°. Nobody has ever made anything cold enough to measure the lowest limit of coldness, which is called

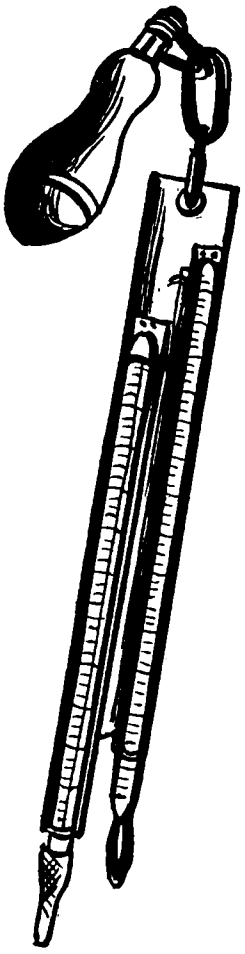


absolute zero, but scientists have come close enough to be able to figure it at −273°C. (C. is the abbreviation for centigrade, F. for Fahrenheit.) This absolute zero is where the Kelvin color temperature scale starts, if you remember. No one has been able even to imagine an upper limit. The center of the sun is supposed to be about 40,000,000°C.

To change degrees centigrade to degrees Fahrenheit, multiply the centigrade temperature by 9/5 and add 32°. To change from Fahrenheit to centigrade, subtract 32°

from the Fahrenheit temperature and multiply what you have left by 5/9.

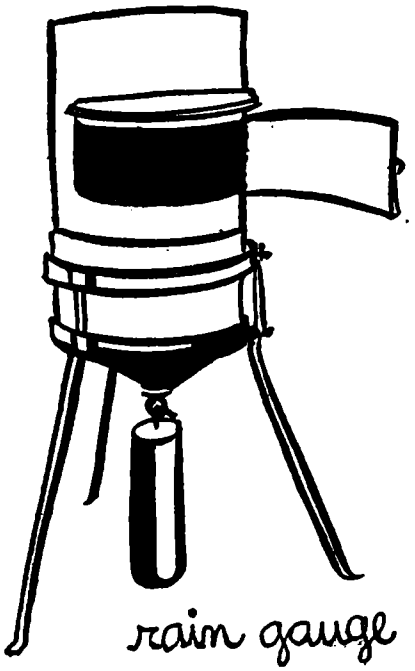
The measurement of the amount of moisture in the atmosphere is expressed as *relative humidity*. In a weather report it is usually given as a percentage. This percentage is figured in relation to the greatest amount of moisture the air could possibly hold at the present temperature. Since the air can hold 100 per cent before it starts to



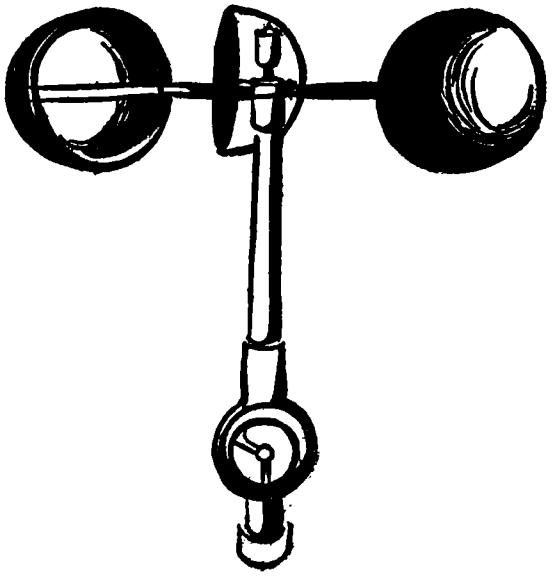
A sling psychrometer measures the moisture in the air.

rain, a humidity of 50 per cent means that the air is holding half the water vapor it can.

An *inch* is the measurement of rainfall or snowfall. It is a fall that covers the surface of the ground to a depth of one inch or that fills a gauge (GAYJ) (which is simply a device for measuring) to a depth of one inch. The weather department's gauges for measuring the depth of rain or snowfall are just big cans with scales of inches marked up the inside walls.



rain gauge



wind velocity is measured by an anemometer.

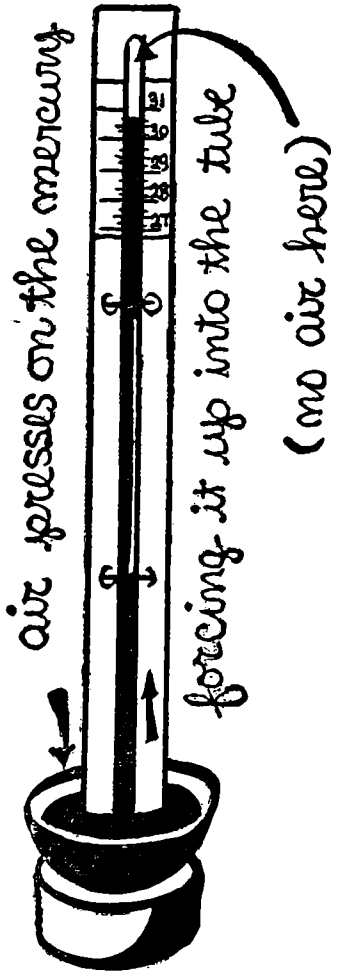
The wind must be caught too, so that it can be measured. It catches in the little cups of the anemometer, spinning them around. The indicator on the bottom shows how fast they are traveling.

The speed of the wind, or its *velocity*, is measured in miles per hour.

An *inch* is also a measure of atmospheric pressure. If you look at the picture of the barometer, you will see that

the scale is marked off in inches. When the pressure starts to rise or fall, it indicates how the weather is going to change.

Atmospheric pressure is the pressing or weight of the atmosphere. The air is pressing down on everything in the world all the time. This pressure is very great because so many miles of air are pushing down. There are about 15 pounds of air pressing on every square inch of you.

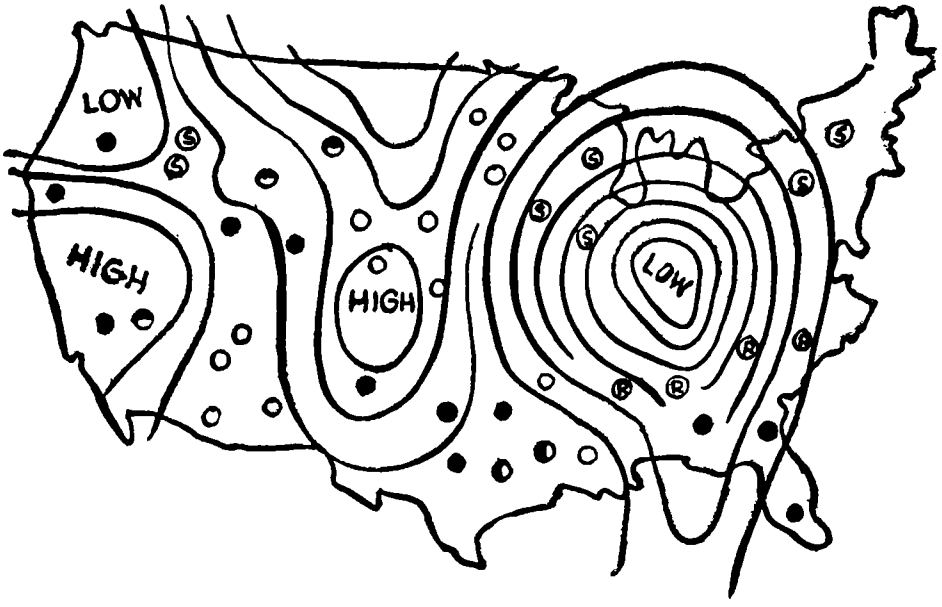


a simple barometer

Atmospheric pressure changes with the weather. If there is a mass of warm air high over an area, the pressure

is less, because warm air is light. Cold air is heavy, so it makes the pressure more. Light, warm air holds much more moisture than cold air can, so when the pressure is low it usually means that a storm is coming. This pressure is measured with a barometer.

When the pressure is high, it means the weather will probably be fair. Air pressure is measured in *millibars*. A millibar is $\frac{1}{1000}$ *bar*, which is the unit for measuring pressure.



Weathermen have a special kind of map that tells them what the weather conditions are and what to expect in any part of the country. Can you tell from the one on this page what the weather in your neighborhood will be like?

SURVEYING

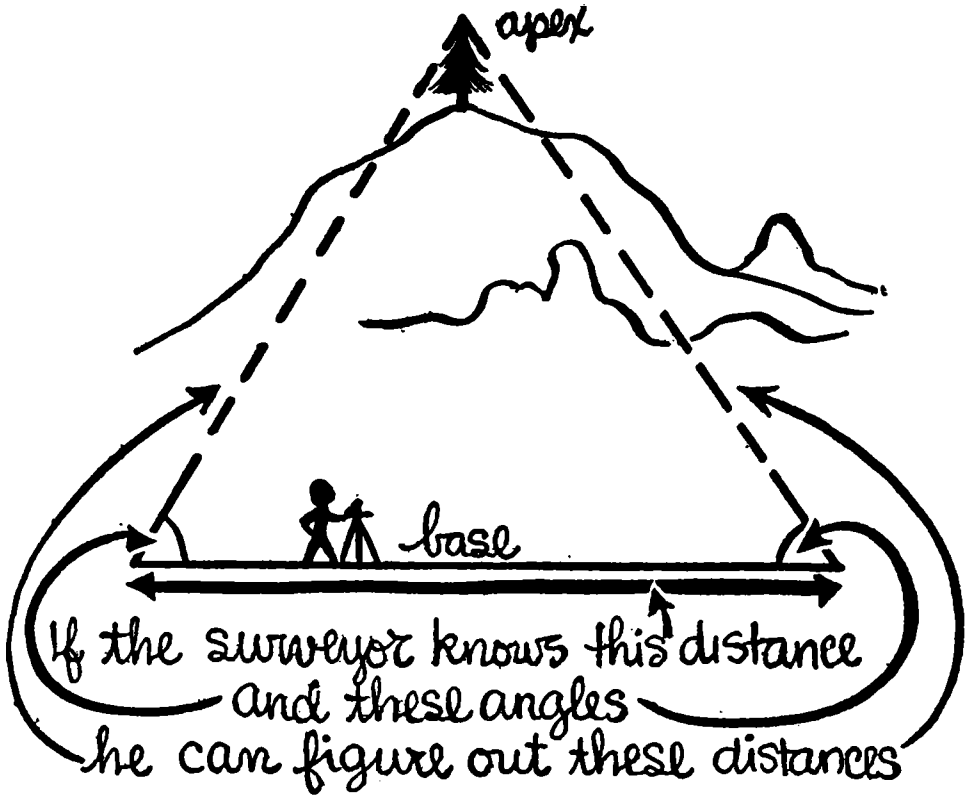
Surveying is a science of measurement. From it we get our maps, the charts of coast lines and mountains, titles to property, or perhaps plans for new roads, towns, or waterways.

In surveying, careful measurements made on the ground are drawn on paper to an exact scale. A single field or an entire country may be surveyed, as ours was, first by explorers and settlers, then again and again as it is built up.

All surveys depend on linear measurement for determining distance. Sometimes, though, there are areas that would be difficult to measure directly. Luckily, surveyors can figure the extent of these areas by measuring angles and then using geometry.

Ways of Measuring

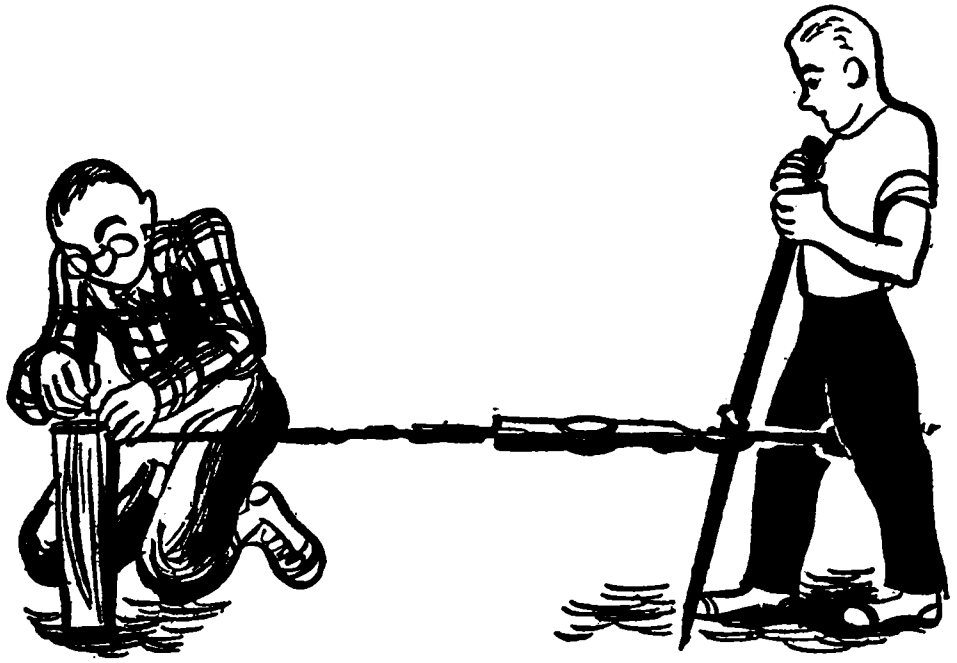
If the surveyors know the length of one distance, this is easy. They divide the land to be measured into a triangle



with the distance they know as the *base*. Then they decide on some object they can see in the distance as the far point—they call it the *apex* of the triangle. With their instruments they sight on this point and get the angles at

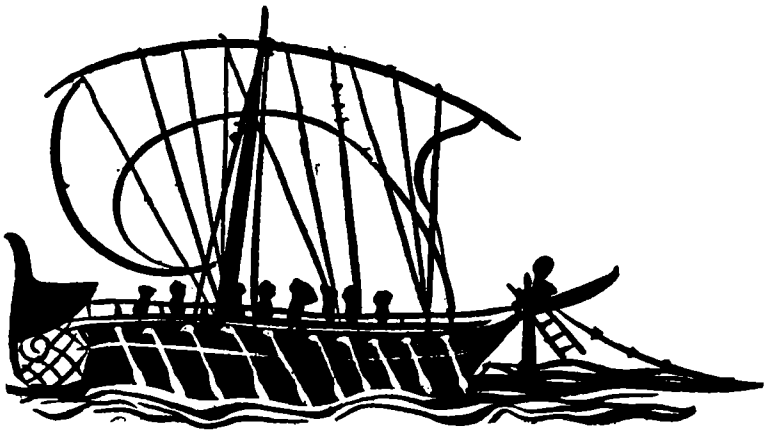
each end of the base. Then, knowing the base length and the measurements of the two angles at the ends of it, they can use geometry to figure out the distances between each end of the base and the point they sighted on.

For all these measurements to be correct, the measurement of the base must be exact. A mistake of one-millionth of a part would make all the other figuring wrong.



There are several ways of measuring the base. Sometimes this distance is measured with steel tapes about 300 feet long and ⅜ inch wide. The tapes may be hung over trestles or even laid along the ground.

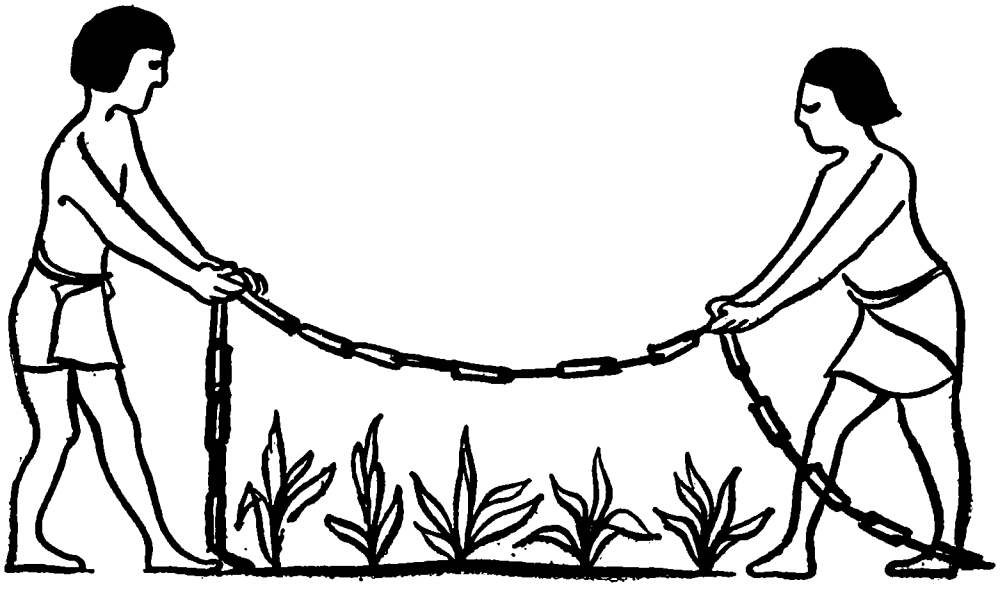
These same tapes divided into meters are used for surveying the coast, too, and rivers and mountains and lakes. Around 300 B.C. the Greeks surveyed their coast, using a knotted, floating line for a tape.



Sometimes, instead of a tape, surveyors use a *chain.* A chain is made out of 100 pieces of wire bent into links, each 7.92 inches long. A surveyor's chain, or Gunter's chain, is 66 feet long.

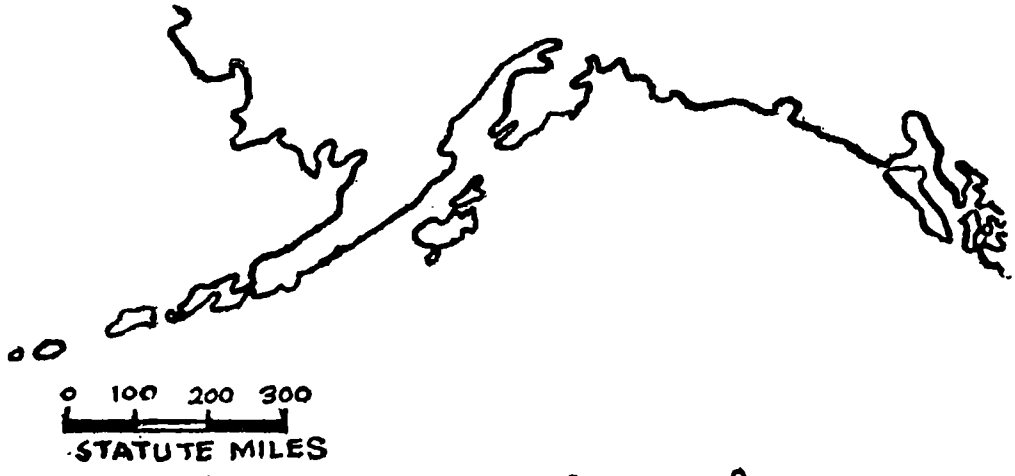
An engineer's chain is used for surveying, too. It is 100 feet long with 1-foot links and the first foot is divided into fractions so that lengths of less than a foot can be measured exactly.

The ancient Egyptians were probably the first people



to survey land accurately. There are pictures in one of their tombs of two men using a chain to survey a field of corn. The simplest, oldest method of making a map was by measuring the ground directly with a chain or rope or tape of a known length.

Somewhere on almost every map you will see a scale of miles. This shows you how many miles of actual distance each inch on the map represents. A large-scale map might show only a small section of area—maybe an inch would represent a mile. A small-scale map could not show much detail—an inch might represent 100 or even 500 miles.



This shows the scale of the map

Area

It's a funny thing that, although the Babylonians divided time exactly and invented circular measurement, they never discovered the simple fact that they could figure area by multiplying length times width.

A very important measurement of area is an *acre.* An acre was originally the amount of land a yoke of oxen could plow in one day. You can see how in the beginning it varied a great deal, depending on whether the farmer and his oxen were lazy or ambitious. At last Henry VIII of England limited an acre to an exact size. It was the

area of a piece of land 40 measuring rods long by 4 rods broad. (These rods were 5½ yards long.) During the middle ages, the length of a rod was determined by lining up 16 men outside of church on Sunday morning, and measuring the combined length of all their left feet.

So the area of an acre was, and still is, 160 square rods, or 4,840 square yards. A piece of ground 200 feet by 200 feet is nearly an acre.

Rods were among the earliest standards of length. The Romans used 10-foot rods with each foot a little over 13 inches long. Now a rod is 5½ yards. Sometimes rods are called poles, too.

Distance

A *mile* is another of the measurements that have come down to us from the Romans. It was originally 1,000 *passus* (or paces). The passus was a Roman measure 5 feet long, or the distance covered by a double step,

from the place one foot left the ground to the place where it was put down for the second time. The mile stayed at 5,000 feet until about 1500, when it was changed to 5,280 feet to make surveying land easier. This way the furlong, which was the commonest land measure at that

time, could be divided into a mile 8 times. About 75 years later Queen Elizabeth established the length of the mile by law.

Sometimes the mile is called a *statute* or *land mile.* It is still 5,280 feet.

In most parts of Europe the mile has been replaced by the kilometer, a measurement of the metric system. A kilometer is about $\frac{5}{8}$ mile.

The nautical or sea mile—1.1515 land miles—is $\frac{1}{21600}$ the great circle of the earth, a minute of circular measurement.

A *furlong* is ⅛ mile. At first it was a furrow long, the length of a furrow in an ordinary field.

The *league* was an old Gaulish measure of distance, varying in different times and different countries from about 2½ to 4½ miles. Nowadays we figure a league at 3 miles. So when the man in *The Charge of the Light Brigade* shouts, "Half a league onward!" he means that the enemy is a mile and a half away.

As a measure of area a *square league* is 5,760 acres.

Laying Out a Town

When surveyors first mapped the land in this country, they started laying out townships. A *township* is made up of 36 square miles, each one called a *section*. They were first marked off just as convenient ways of dividing big areas of land. Usually a town grew up in the township, with its own local government.

A *block* is a varying unit of measure. In any town or city it is a unit of land divided for building convenience with streets on all four sides. In some places a block is called a *square*. In Texas, though, when a block is used as a unit of measure, it is a piece of land at least a mile square.

Roads

Grade is a measurement of slope from a level surface. It is usually used for roads and can be expressed in several

different ways. Sometimes it is measured in degrees. A road rising from the horizontal at an angle of 15 degrees would have a 15-degree grade. Sometimes grade is

expressed in feet per 100 feet or feet per mile. Sometimes it is expressed in percentage. A 10 per cent grade would rise 10 feet every 100 feet of its length.

Grading a road seems like a wonderful feat of modern engineering, but the ancient Romans graded their roads so well that we know they must have had surveying instruments with which to do the jobs.

COOKING

Cooking measurements are all the ordinary dry and liquid measures, but sometimes it is handy to know what different measures are equal to.

Did you know that—

Two cups of liquid equal 1 pint?

Four cups equal 1 quart?

One pint of liquid equals 1 pound? Most liquids weigh about the same, except the thick, syrupy ones like molasses.

Two cups of granulated sugar
Two and a half cups of confectioners' sugar
Two and two-thirds cups of brown sugar
} equal 1 pound?

Four cups of flour equal 1 pound?

Two cups of butter equal 1 pound?

One-quarter pound of butter equals ½ cup?

Two cups of chopped meat equal 1 pound?

Twelve tablespoons of flour or sugar equal 1 cup?

Two tablespoons of butter or sugar equal 1 ounce?

Four tablespoons of flour equal 1 ounce?

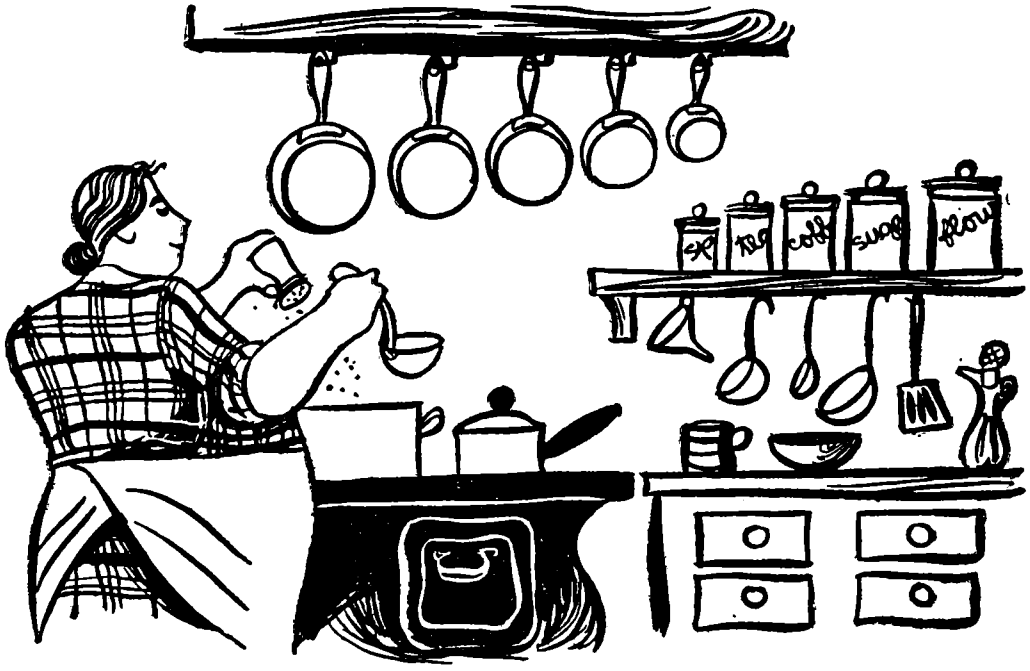
Two tablespoons of liquid equal 1 ounce?

One tablespoon of salt equals 1 ounce?

Sixty drops of liquid, like water, equal one teaspoon?

Three teaspoons equal 1 tablespoon?

Sixteen tablespoons equal 1 cup?



As in all sciences, the measurements in cooking should be absolutely level. You probably know some cooks, though, who use a handful of this and a pinch or two of that, and get wonderful things to eat just the same.

MEDICINE

There are a number of measurements that help your doctor to know how you are. Ever since the sixteenth and seventeenth centuries, when scientists first began to find out how the human body really works, they have known that things like temperature were important. But they couldn't always measure them as well as they do now.

Metabolism

Chemical changes are always taking place in your body to build it up and provide the energy to keep it going, so you can do the things you do every day. This process is called *metabolism* (meh-TAB-oh-lizm). Since these changes produce heat and energy in your body, metabolism can be measured as the heat that is produced. The unit of measurement for this heat is the calorie. It is measured on a device called a calorimeter.

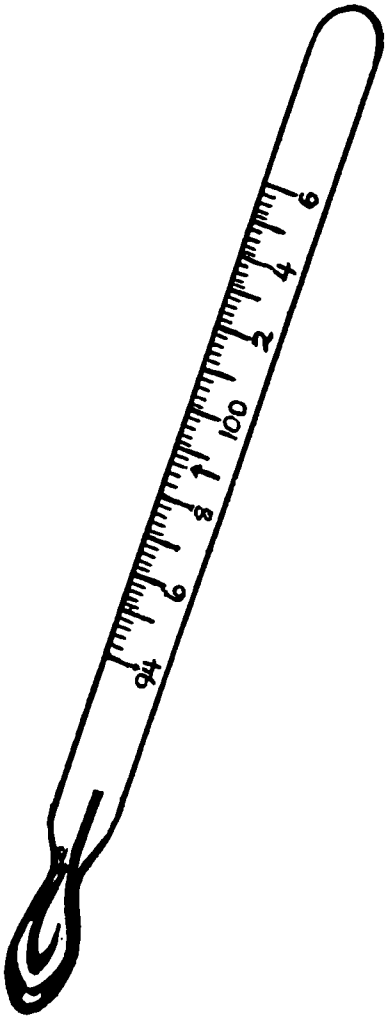
1 white cell to more than 600 red ones.

Blood Count

You have two kinds of cells in your blood, red ones and white ones. The red ones are for everyday use and the white ones are there to fight disease or infection. When you are sick, the white ones multiply very fast to attack the enemy. When the doctor takes your *blood count*, he is

counting the number of red and white blood cells in a definite volume of blood.

Your *body temperature* is the heat of your body. When it is normal, it is about 98.6°F. When you are sick, it may

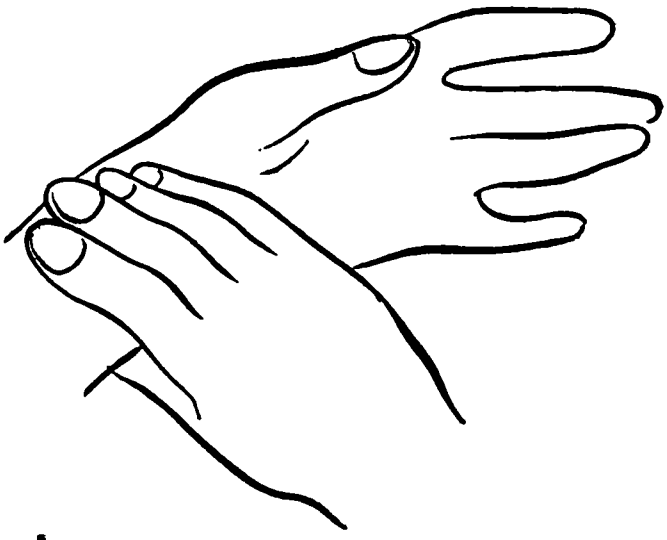


The mercury in the bulb goes up inside the thermometer to register your temperature.

go higher or lower. Fish and reptiles have no body temperatures of their own. Their bodies take on the tempera-

tures of their surroundings. We call them *cold-blooded.*

Your *pulse rate* is the number of times your heart beats every minute, usually from 70 to 75 times. When you



The doctor never uses his thumb when he takes your pulse, because it has a strong pulse-beat too.

are sick or excited or frightened, it may beat much, much faster. Babies have a very fast pulse beat, too, but as people get older it gets slower all the time.

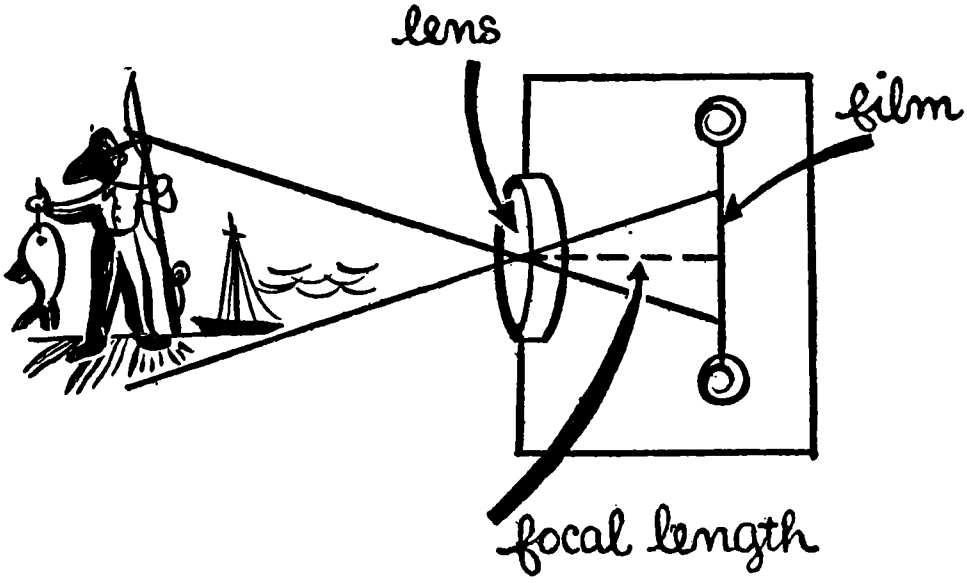
Larger animals have slower heartbeats than smaller ones. If you ever took a horse's pulse, you would find that its heart beats only from 28 to 40 times a minute.

Another thing a doctor measures is *blood pressure.* This is the amount of pressure your heart puts on the walls of your arteries as it pumps blood through them. The doctor's instrument measures it in millimeters of mercury. A normal blood pressure can be from 100 to 140 millimeters.

PHOTOGRAPHY

There are three important measurements connected with photography.

Focal length is the distance from the lens of a camera to the image of a distant object. (That word "image" is the important one.) It is the distance not from the lens to the



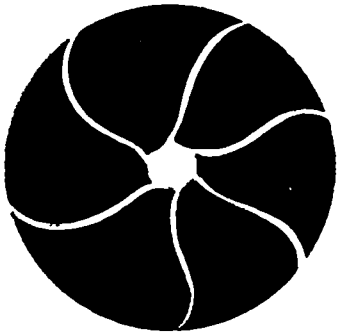
object but from the lens to the picture of that object on the film behind the lens.

When a faraway object is *in focus*, the distance between the lens and the film is called the focal length. You cannot change the focal length of your camera. But you can change the focus by adjusting the lens so that it projects the image of what you are taking clearly onto the film.

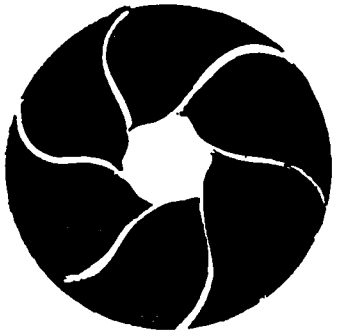
Focal length can be measured either in inches or in fractions of meters. A moving-picture camera, for in-

stance, may have a focal length of 2 inches. In meters the same lens would be a 50-millimeter lens. Cameramen will change the lenses on their cameras to get various kinds of pictures. From the same distance a lens of one focal length will get everything in the scene, while one of another will get only a close-up of one face.

F. stop is a measure of the amount of light passing through the lens. When there is a lot of light, you change



If the hole in the iris is small, the f stop number is big.



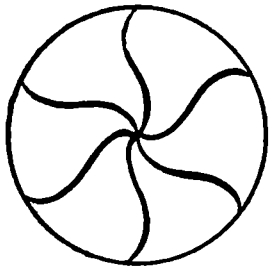
If a lot of light comes through, the number is small.

the f. stop to allow less through to the film so the picture won't be too light, or overexposed. Every time the lens is closed 1 f. stop, the amount of light coming into the camera is reduced by half. The larger the number on the f. stop, the less the light that comes in.

F. stops usually run from 1.9, which lets in the most light, to 32, which lets in the least.

Shutter speed is the speed of the opening and closing of the shutter, which lets light through to the lens. When cameras were first invented, light had to come through

for several minutes in order to expose the film. Now film works faster, so 1 second is considered rather a long time



The shutter looks like the iris, but it opens and shuts completely.

for the shutter to be open. Shutter speeds usually are anywhere from 1 second to $\frac{1}{1200}$ second.

GUNS AND BALLISTICS

Although the Chinese had been using gunpowder to set off firecrackers for hundreds of years, it was not used

in Europe until the fourteenth century. First it was used as an explosive. Then, a short time later, someone invented a gun in which a charge of gunpowder was exploded, pushing a bullet out of the barrel at great speed.

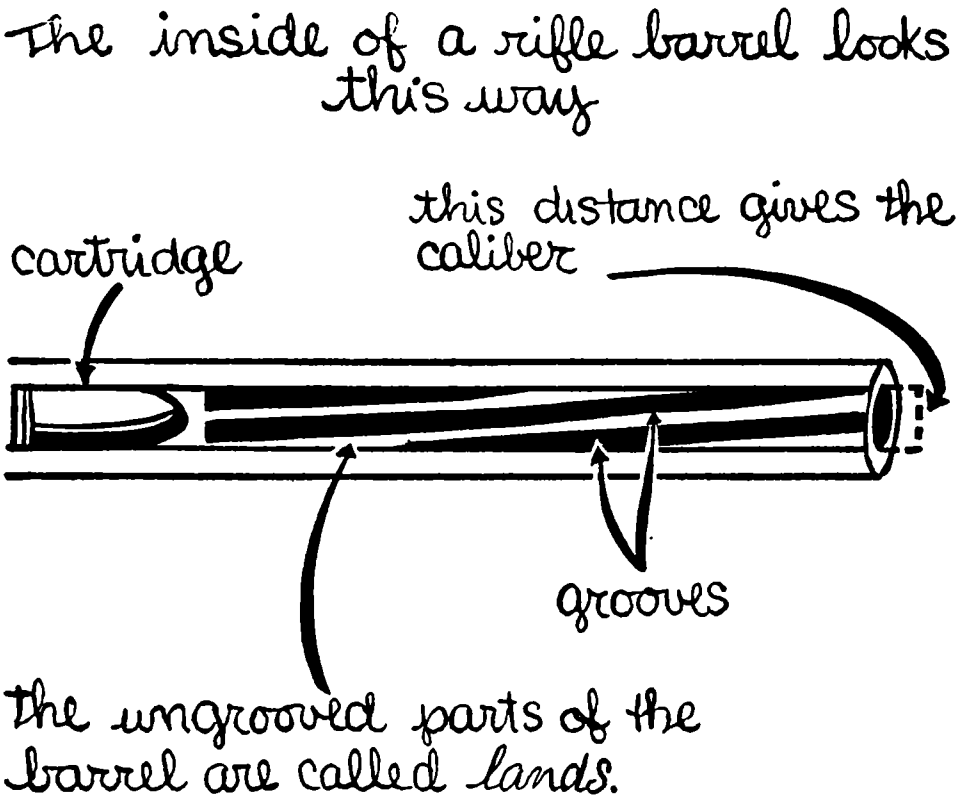
The first gun was just an iron tube, closed at one end and fastened to a wooden stock. There was a small hole in the top of the barrel near the stock. The gun was loaded, a lighted ember thrust through the hole, and the gun went off.

Guns and bullets have been greatly improved since those first ones, but the principle that makes the bullet fly out is still exactly the same. When the gunpowder is exploded, it produces a lot of heat, which makes the gas created by the explosion expand very rapidly. This expansion takes place inside the barrel of the gun, and since the sides and back of the gun are very strong, the only way the gas can escape is by pushing the bullet up through the barrel and out of the gun, which it does at a terrific speed.

Now the making of guns and charges, and the study of how bullets act when they leave a gun, are exact sciences. It is this study of bullets that is called ballistics (baa-LIS-ticks). Like other sciences, these have very special measures. Here are a few.

Caliber is a measurement that is used for rifles. A rifle is a gun whose barrel is bored with a series of spiral

grooves. These grooves spin the bullet before it leaves the gun to make it go farther and faster in a straight line. (The grooves in every rifle or pistol become worn in a slightly different way, so that the markings on a bullet from each gun are as individual as fingerprints.) Caliber is the measurement of the diameter, or width, of the bore

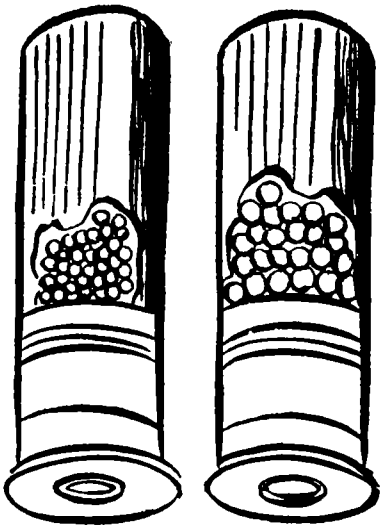

The inside of a rifle barrel looks this way
this distance gives the caliber
cartridge
grooves
the ungrooved parts of the barrel are called lands.

of any rifle, pistol, or cannon. The hole in the barrel is called the *bore*. Caliber is measured in inches for cannon and hundredths of an inch for small arms. (In the metric system it is measured in centimeters or millimeters, which are hundredths or thousandths of a meter.)

When a rifle is a .22 caliber, for instance, it has a bore $22\frac{2}{100}$ inch across. The depth of the grooves isn't counted.

Gauge is the measurement of the diameter of the barrel of a shotgun. A shotgun usually has a smooth bore. It shoots a lot of small pellets, or shot, at one time.

This is how gauge was first established. If one round ball were made out of a pound of lead, the diameter of that shot and the gun barrel that it fitted was 1 gauge. If the pound of lead was divided into 4 balls, the gun was 4 gauge, and if into 10 balls, the gun was 10 gauge. Today these gauges have become standard as the way of measuring the size of a shotgun barrel, but there are different kinds of cartridges for each gauge. Any gauge shotgun may shoot any number of pellets.

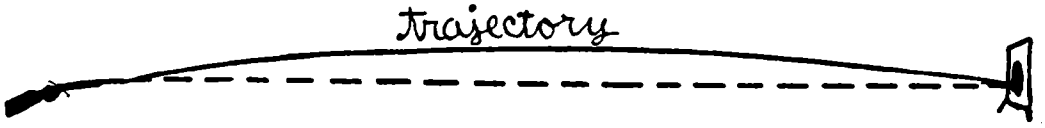


Shotgun shells hold different sizes of shot

Muzzle velocity is the measurement of the number of feet the bullet would travel in 1 second, if it continued at the same speed at which it was traveling when it left the

muzzle of the gun. This speed is measured in foot-seconds (which is another way of saying "feet per second"). Actually, the velocity of a bullet, the speed at which it is traveling, drops as soon as it leaves the gun. This drop in speed depends not only on the weight and shape of the bullet, but also on the wind blowing at the moment.

Trajectory (tra-JECK-toh-ree) is the measurement of the arc over which the bullet travels before it hits a target.



Unless it is shot at very high speed into a target only a short distance away, the bullet doesn't move in a straight line but starts to drop. The farther you are shooting, the higher you have to aim to allow for this drop.

THE METRIC SYSTEM

EVERY CIVILIZED COUNTRY in the world is either obliged by law or permitted for convenience to use the metric system of weights and measures.

Although the United States and England ordinarily do not use the metric system except for scientific purposes, we use the two basic metric standards as our standards. The *meter* is the standard for length, the *kilogram* for mass, and from an exact comparison with these standards we figure our standard yard and pound. The meter is

39.37 inches long, and the kilogram weighs 2.2046 pounds.

The metric system was introduced by the French in 1790, following their revolution. It was part of their plan to start their whole social and economic life afresh, without any ties to the past. So a group of scientists got together to figure out a new system of weights and measures.

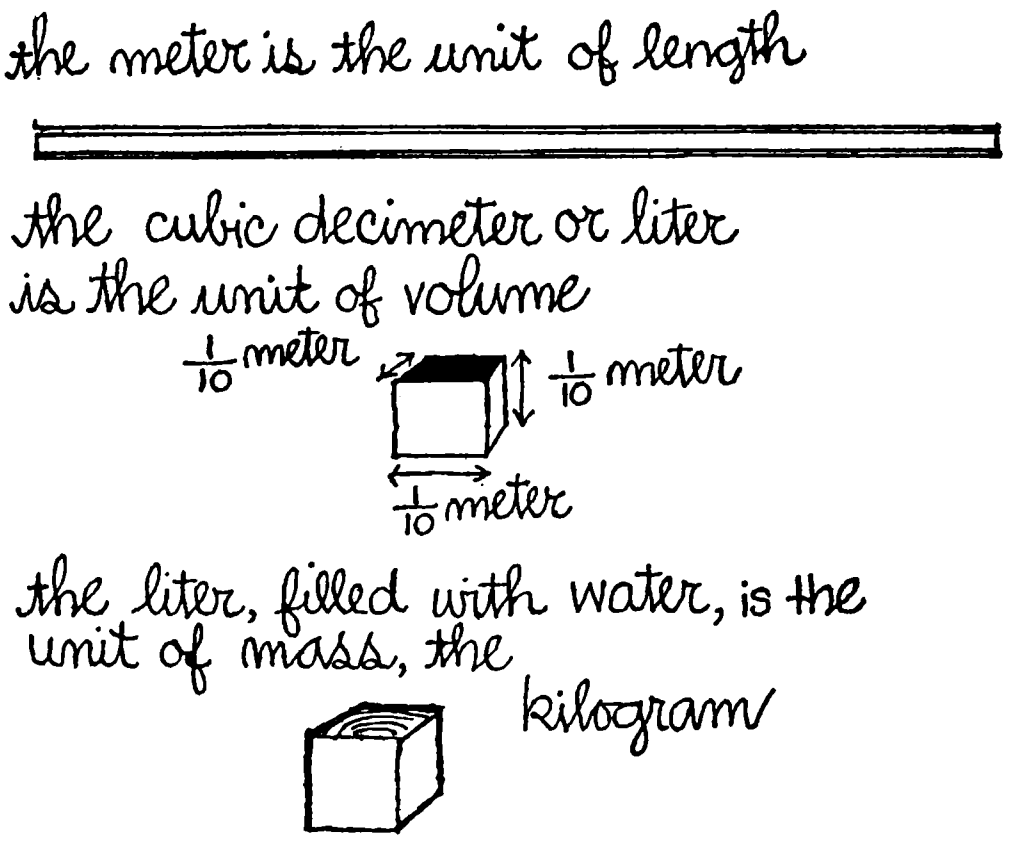
The *meter*, the fundamental unit of length, was originally supposed to be 1/10 millionth part of the quadrant of the earth, using the distance from the North Pole to the equator. But in the eighteenth century precision instruments were not as fine as they are today, and somewhere an error was made in measurement. By the time the scientists discovered the mistake, the length of the meter was so well established that it was kept as it was.

At the time when the French invented the metric system, the systems in the surrounding European countries were in great confusion. Every town or local government had its own variation of the system in use, and there were no standards. The French system was simple, and there was such a great need for one throughout Europe that it spread everywhere. In fact, the slowest country to bring it into common use was France itself, where it did not become popular for another 40 years.

The English and the Americans were perfectly satis-

fied with their system so there was no need to change, although the suggestion has been made many times. In 1866 Congress made the use of the metric system lawful where it was more convenient, but it has never come into general use even though we use its two fundamental units as our standards.

One thing that makes the metric system simpler than our own is that it is a simple decimal system that goes by tens. Another is the direct relationship of the units of length, weight, and capacity to one another.


the meter is the unit of length
the cubic decimeter or liter is the unit of volume
1/10 meter
1/10 meter
1/10 meter
the liter, filled with water, is the unit of mass, the
kilogram

The unit of length is the meter. The unit of mass is the kilogram. ("Kilo" means "thousand," so the word means

a thousand grams.) This is the way the scientists decided on the mass of the kilogram. First they made a cube with each side $\frac{1}{10}$ meter long, or not quite 4 inches. This was called the cubic decimeter (which means $\frac{1}{10}$ meter) or the *liter*, and it was decided that that would be the unit of volume. Then they decided that the mass of pure water which would fill this cubic decimeter would be the unit of mass, the kilogram.

How the Metric System Goes

If you know that

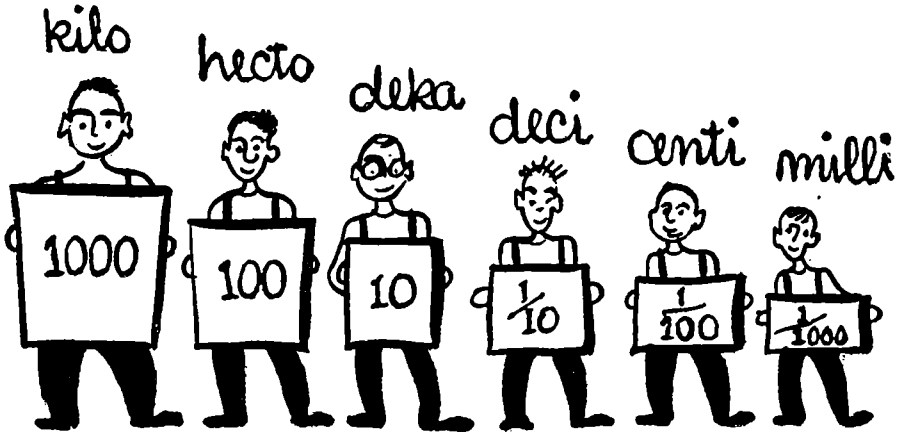
a meter is 39.37 inches long,
a gram is 15.43 grains,
a liter is 0.946 quart,

you can tell right away the value of any weight or measurement in the metric system. Because unlike our system, in which every weight and measure has a separate name that doesn't give any real clue to its value, the names of those in the metric system tell you exactly what they are.

There are six prefixes that can be attached to any of the units, and each of these prefixes means a number.

Milli means $\frac{1}{1000}$
Centi means $\frac{1}{100}$
Deci means $\frac{1}{10}$
Deka means 10
Hecto means 100
Kilo means 1,000

Any of these prefixes attached to meter, gram, or liter tells you exactly what the value is.



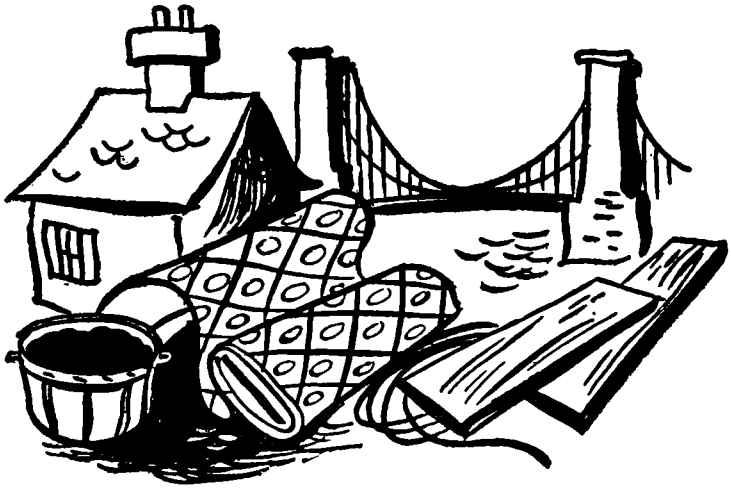
A kilogram is 1,000 grams, and a hectogram is 100. A milliliter is $\frac{1}{1000}$ liter. No matter how you mix the prefixes up, or which words you attach them to, you can always tell.

Sometimes, when the measurements are for scientific use, it is convenient to multiply or divide the basic units by more than a thousand. So some special new prefixes have been introduced.

MYRIA means 10,000
MEGA means 1,000,000
MICRO means 1/1,000,000

So many scientific things are measured in micrometers now that scientists have made up a shorter word, *micron.* And there is one even smaller than that—a millimicron is a thousandth of a millionth of a meter. This may seem too small to measure anything, but there are waves of light even shorter than a millimicron.

The meter is used for measuring all kinds of dry goods and materials, for building and engineering, and for any purpose where the yard or foot can be used. A meter is about 10 per cent longer than a yard. The old English

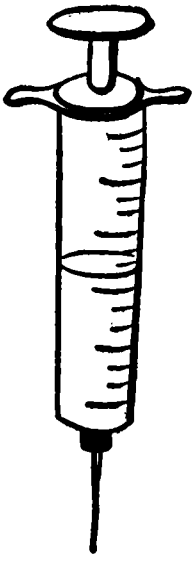


yard, which was abandoned in 1439, was 39.66 inches, almost exactly equal to the meter of today.

Centimeters and millimeters are used instead of inches in constructing machinery, in making furniture, and in measuring book and paper sizes. A centimeter is about $\frac{2}{5}$ inch and a millimeter is about $\frac{1}{25}$ inch. The kilometer is used instead of the mile. It is about $\frac{5}{8}$ mile.

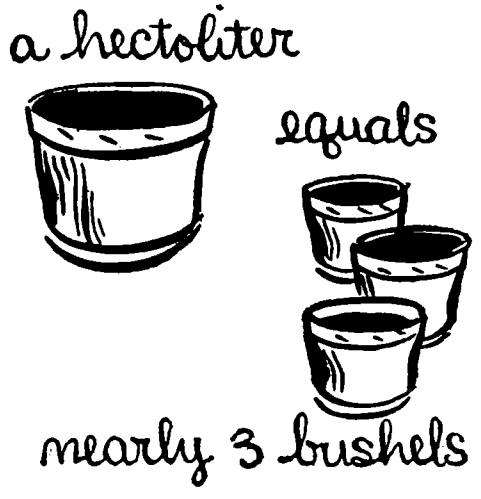
Measurements of area are made by multiplying the length by the width, just as we do. Instead of using an acre as the unit of area, the metric system unit is 10

meters square and is called an *are*. The *hectare*, which is 100 meters square, is equal to about 2½ acres. Where we would use square yards and square inches, the metric system uses square meters and square centimeters.



In measuring volume, or what a space will hold, the cubic meter is used. It is used for reckoning the tonnage of ships, the contents of tanks or reservoirs, for measuring timber or filling in land.

For small volumes of liquids there is the milliliter. A milliliter (MIL-i-lee-ter) of water weighs about one gram, so it is a handy measure in chemistry, pharmacy, medicine, and other scientific work. The measurement "cc.," which is used by doctors and chemists among others, is the abbreviation for "cubic centimeter." But it also stands for a milliliter, or ml, which is exactly the same.

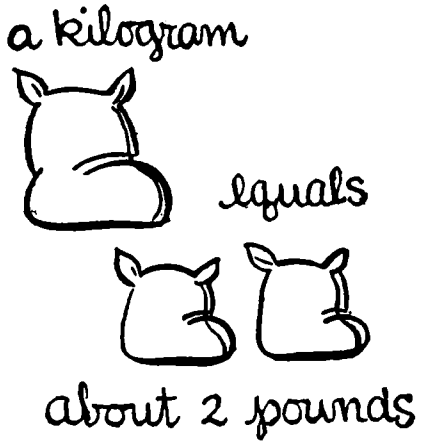


The *hectoliter* is equal to nearly 3 bushels, and is used for the things we measure in bushels.

Things we count in quarts or gallons are measured in liters. A liter is 5 per cent larger than our liquid quart and 10 per cent smaller than our dry quart.

A metric ton, which is 1,000 kilograms, is about halfway between our long and short tons, and is used in place of either one.

And the kilogram, which is a little more than 2 pounds, is used in everyday trade where we use a pound.



Troy and apothecary weights are all replaced by the gram, either multiplied or divided.

At the beginning of the nineteenth century, John Quincy Adams tried to persuade Congress to make the metric system the official system of weights and measures for the United States. Now, 150 years later, it is coming into wider use, as standards become more exact, to keep pace with our need for precision in science and industry.

THE NATIONAL BUREAU OF STANDARDS

WHEN THE Constitution of the United States was written, it gave Congress the power, "to fix the standards of weights and measures." But there were so many things to do in the new country that it was a long time before any-

body got around to it. Standards were different in every state and in almost every port. An importer bringing in foreign goods would shop around for the best port at which to land them. According to the different standards

used, he would have less goods at certain ports than at others and so would have to pay less tax.

This was so hard on the Treasury Department that in 1832 it established the Office of Weights and Measures in Washington. In 1836 the office was told to give each state government a duplicate set of the official weights and measures. Once in a while these state standards and those used by manufacturers were compared for accuracy with the national standards, but that was about all the office did.

In 1875 the International Bureau of Weights and Measures was established near Paris, and in the years following, England and Germany set up departments of their own. American manufacturers, who were sending their instruments abroad to be checked, kept asking for a similar laboratory here. Finally, in 1901, the National Bureau of Standards was established.

The National Bureau of Standards is now part of the Department of Commerce. It is the job of its employees to develop and maintain the working standards used in science and industry, in commerce and engineering. They compare these standards for accuracy and at the same time do all kinds of research on old and new materials.

The National Standards

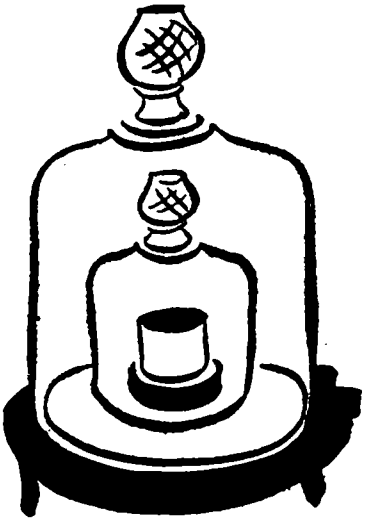
In an earlier part of the book we talked about the standard for measuring the meter, from which we take, in turn, our standard for the yard. Now that we use wavelengths of light instead of the platinum-iridium bar engraved

with fine lines as our standard, we can measure a meter accurately to within 1/10,000,000 of an inch. The old meter bar was accurate to only 1/1,000,000 of an inch. This seems very close, but it is not accurate enough for modern scientific measurements.

The old standard meter had to be returned, occasionally, to Sevres, France, to be compared and adjusted to the original standard meter there. But the new standard will never need adjustment. Wavelengths of light from a particular source never vary in length if the conditions under which they are emitted are scientifically controlled.

Around the world, the old standard meters have now become historical treasures.

Kilogram Number 20, which is the twentieth copy of the original kilogram, is the national standard of mass. It is a cylinder about 1½ inches high, and made of the same metals used in the meter. This particular combination of metals is used because it is the most durable that could be found and the least affected by temperature and atmospheric changes.



You can see in the picture how carefully the standard kilogram is kept—under two bell jars. Kilogram Number 20 and *its* copy, Kilogram Number 4, are weighed and compared against other kilograms that are used as standards all over the country.

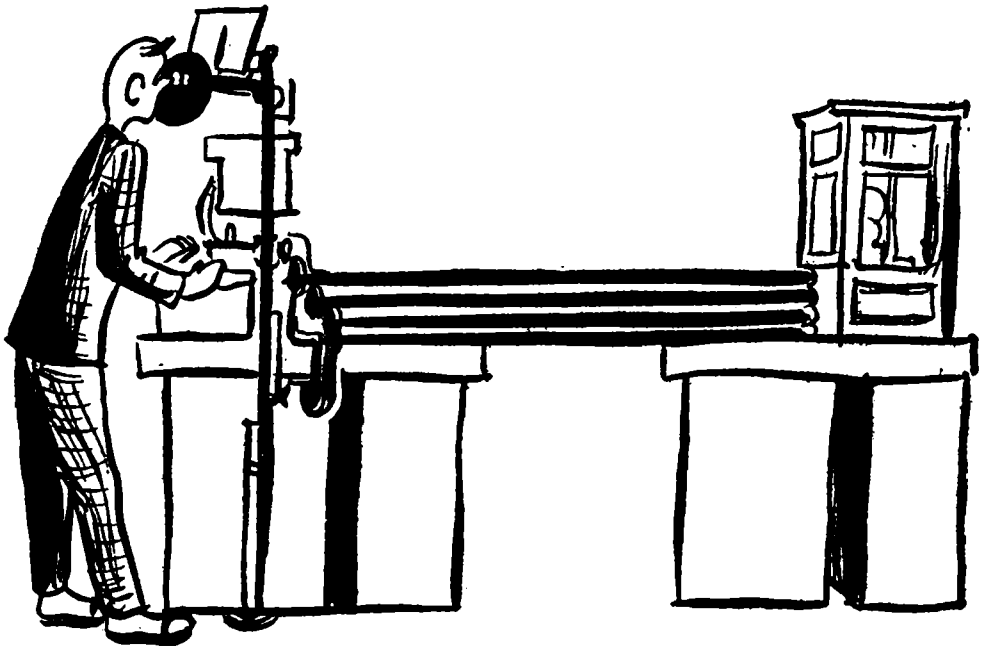
In 1937, when Number 20 was 50 years old, it was taken back to Paris to be compared with the original kilogram. Their values were still the same to 1/50 millionth part.

About Comparing

Industrial and commercial standards of length and mass are compared often with the national standards to make sure that they are accurate.

Standards of length are compared with great precision on a machine called a *comparator*. The adjustments on the comparator are so delicate and the microscope sight so powerful that the inspector can detect a difference as slight as a few millionths of an inch. A millionth of an inch is so small that a fly bends a steel bar that much by sitting on it.

When the standard weights are compared with the



standard kilogram, such delicate balances are used that a difference of no more than one part in 100 million can be found. The man who works this balance stands 10 feet away behind a shield so that the heat from his body won't affect the reading. He works the balances with levers.

Flatness is another industrial measurement that must be exact to a few millionths of an inch. In some machinery one part must move against another for cutting, and so the surfaces must come together perfectly. Very often gauges are used to test the precision of other parts that are being made. These gauges must be perfectly flat, too, in order to measure the variations of the parts that are being tested.

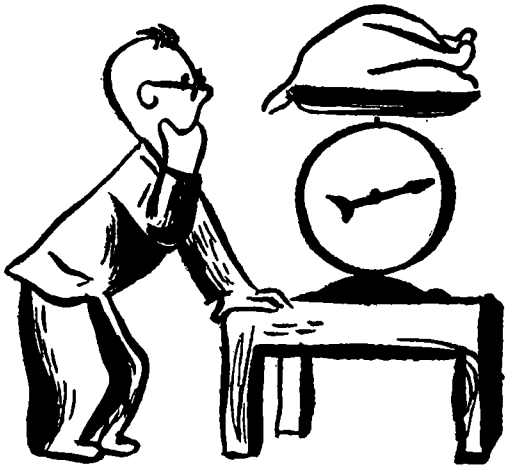
Measurements as exact as these may seem silly at first, but they are very important to modern science, industry, and medicine, and so to you. Many of the necessities of modern life can be manufactured only because we have learned to make exact measurements. Light bulbs, radios, automobiles, and the machinery that makes most of the things around us, depend on them.

Just because he needed a cylinder so accurate that steam could not escape around a piston working inside of it, James Watt could not build a full-sized steam engine from his model for 10 years. He had to wait until another man invented a machine that could bore the cylinder so exactly.

The People Who Work in the Bureau

Usually about 2,000 people work for the Bureau of Standards. One group does scientific and technical re-

search and testing. Another group makes and compares all those standards used in commerce. The last group



runs the Bureau itself—the offices, the laboratories, the workshop. There are people working with weights and measures, with electricity, heat and power, industrial materials, and many other things.

They check scales that are so fine that they can weigh $\frac{1}{1000}$ gram, and giant railroad scales that can weigh a load of 100,000 pounds.

They test the capacity of milk bottles and gasoline pumps and the volume of the measuring tubes used in the chemical laboratories that make powerful drugs and medicines.

They keep a standard clock that measures time without gaining or losing over a second or two in a century.

With electrometers they test electric voltages. In a huge sphere they measure the amounts of light given off by electric light bulbs. In tanks of water they test all kinds of thermometers for accuracy.

And the Machines

In a laboratory room more than 10 stories high a huge X-ray machine tests X-ray voltages.

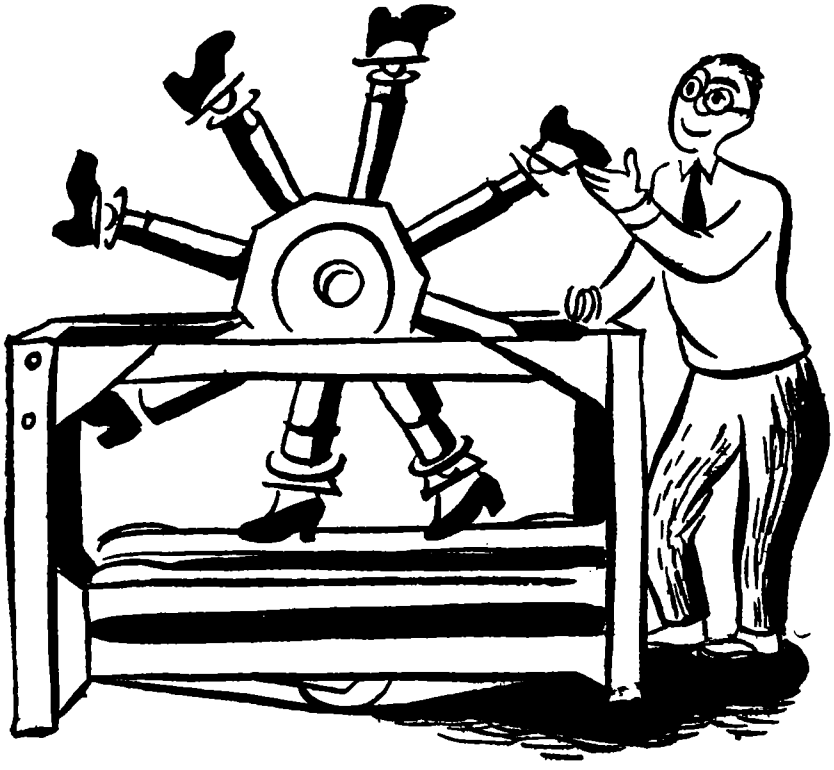
Models of buildings, airplanes, and automobiles are tried out in a big wind tunnel. Before the Empire State Building was constructed, a model of it was tested in this tunnel to see what stresses and strains high velocities of wind would put on the structure. There had never been such a high building, so nobody was sure.

Another tunnel is used to test the steel tapes used in making surveys of our coasts and seas, of plains, mountains, lakes, and rivers.

There is a machine that wears out shoes and another that wears out floors and pavements. There is a great press, three stories high, that crushes walls to see how much dead weight they will hold, and there is a house that is set on fire to see at what temperatures different materials will burn.

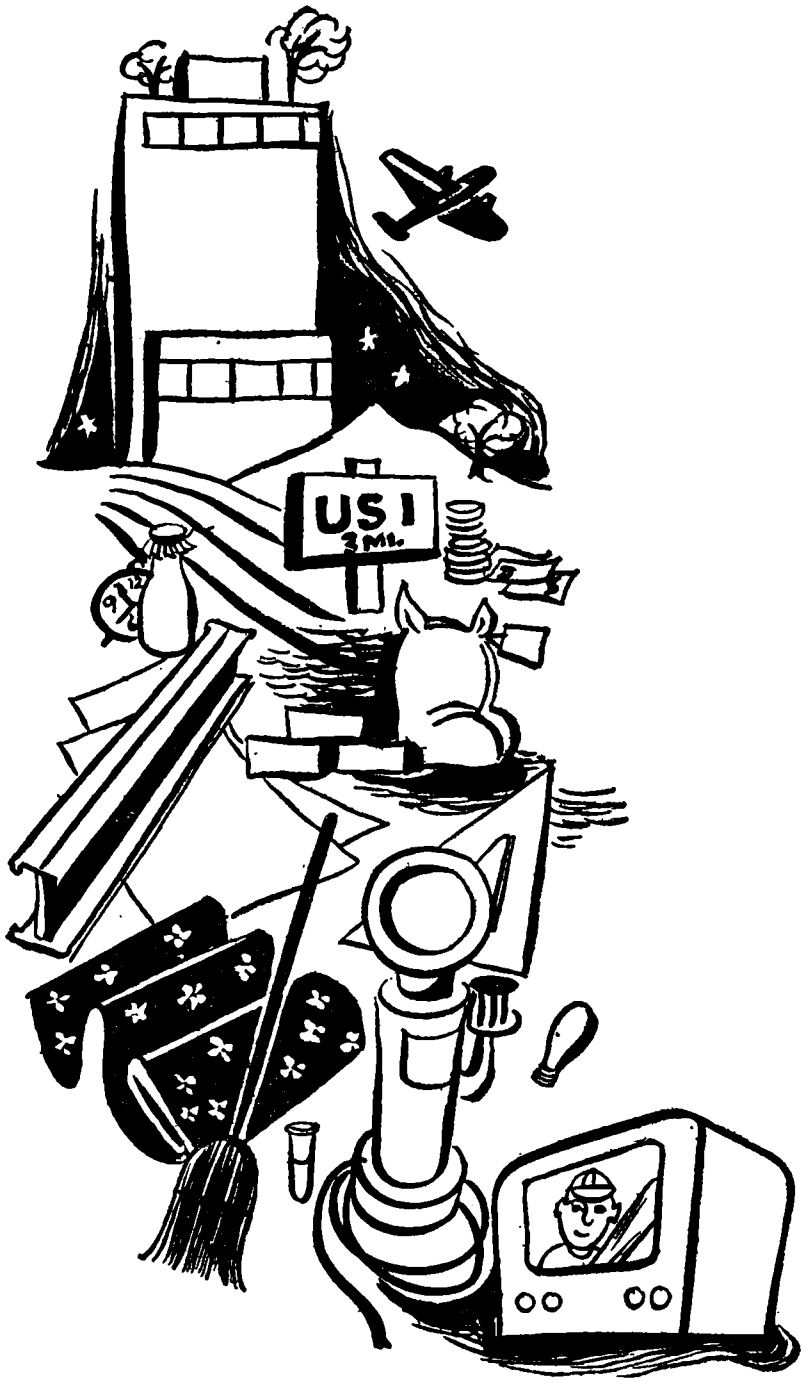
The Bureau's workers do other types of work besides just checking and maintaining standards of measurement. They are always working to develop more precise measuring instruments and ways of measuring, and they do a great amount of test work for the government. The government has to buy mountains of things every year—

concrete for roads and streets and dams, materials for public buildings, steel and silverware, food and brooms, pajamas and shoes, and thousands of other things. The Bureau of Standards tests and checks these purchases all the time. And besides all this they do research for the government in physics, chemistry, and engineering.



Research on radio-controlled bombs, special fuses, the instrument landing system that our planes use, and the atomic bomb all started in the Bureau of Standards.

Very few of the products of science and industry would be possible without exact measurements of the kinds we have talked about. Measuring began even before man was civilized, and civilization has grown as we have found new ways to measure.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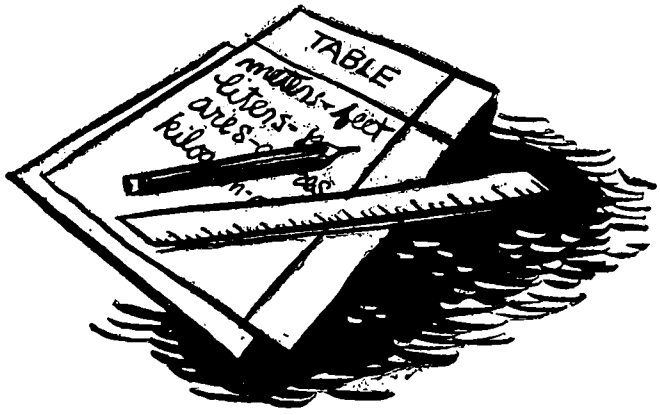
FOR A QUICK LOOK
TABLES OF WEIGHTS AND MEASURES



Avoirdupois Weight

27 11/32 grains (*gr.*) ..... 1 dram (*dr.*)
16 drams ..... 1 ounce (*oz.*), 437½ grains
16 ounces ..... 1 pound (*lb.*), 256 drams, 7,000 grains
100 pounds ..... 1 hundredweight (*cwt.*), 1,600 ounces
112 pounds ..... 1 long hundredweight (*l. cwt.*)
20 hundredweight ..... 1 ton (*tn.*), 2,000 pounds
20 long hundredweight ..... 1 long ton (*l. tn.*), 2,240 pounds

Troy Weight

24 grains (*gr.*) ..... 1 pennyweight (*dwt.*)
20 pennyweights ..... 1 ounce (*oz. t.*), 480 grains
12 ounces ..... 1 pound (*lb. t.*), 240 pennyweights, 5,760 grains

Apothecaries' Weight

20 grains (*gr.*).....1 scruple (*s. ap.* or ℈)
3 scruples.....1 dram (*dr. ap.* or ʒ), 60 grains
8 drams.....1 ounce (*oz. ap.* or ℥), 24 scruples, 480 grains
12 ounces.....1 pound (*lb. ap.* or ℔), 96 drams, 288 scruples, 5,760 grains

Linear Measure

12 inches (*in.*).....1 foot (*ft.*)
3 feet.....1 yard (*yd.*), 36 inches
5½ yards.....1 rod (*rd.*), 16½ feet
40 rods.....1 furlong (*fur.*), 220 yards, 660 feet
8 furlongs.....1 statute mile (*mi.*), 1,760 yards, 5,280 feet
3 miles.....1 league (*l.*), 5,280 yards

Square Measure

144 square inches (*sq. in.*).....1 square foot (*sq. ft.*)
9 square feet.....1 square yard (*sq. yd.*), 1,296 square inches
30¼ square yards.....1 square rod (*sq. rd.*), 272¼ square feet
160 square rods.....1 acre (*A.*), 4,840 square yards
640 acres.....1 square mile (*sq. mi.*), 3,097,600 square yards
36 square miles.....1 township

Cubic Measure

1,728 cubic inches (*cu. in.*).....1 cubic foot (*cu. ft.*)
27 cubic feet.....1 cubic yard (*cu. yd.*)
144 cubic inches.....1 board foot
128 cubic feet.....1 cord

CHAIN MEASURE — *Gunter's, or surveyor's, chain*

7.92 inches (*in.*) ..... 1 link (*li.*)
100 links ..... 1 chain (*ch.*)
80 chains ..... 1 mile (*mi.*)

Engineer's chain

12 inches ..... 1 link
100 links ..... 1 chain
52.8 chains ..... 1 mile

SURVEYOR'S AREA MEASURE

625 square links (*sq. li.*) ..... 1 square rod or square pole (*sq. p.*)
16 square rods ..... 1 square chain (*sq. ch.*), surveyor's
10 square chains ..... 1 acre (*A.*)
640 acres ..... 1 square mile (*sq. mi.*)
36 square miles ..... 1 township

LIQUID MEASURE

4 gills (*gi.*).....1 pint (*pt.*)
2 pints.....1 quart (*qt.*), 8 gills
4 quarts.....1 gallon (*gal.*), 8 pints, 32 gills
31½ gallons.....1 barrel (*bbl.*), 126 quarts,
2 barrels.....1 hogshead (*hhd.*), 63 gallons, 252 quarts

APOTHECARIES FLUID MEASURE

60 minims (*min.* or ♏).....1 fluid dram (*fl. dr.* or f℥)
8 fluid drams.....1 fluid ounce (*fl. oz.* or f℥), 480 minims
16 fluid ounces.....1 pint (*o.*), 128 fluid drams, 7,680 minims
8 pints.....1 gallon (*C.*), 128 fluid ounces, 1,024 fluid drams

Dry Measure

2 pints (*pt.*).....1 quart (*qt.*)
8 quarts.....1 peck (*pk.*), 16 pints
4 pecks.....1 bushel (*bu.*), 32 quarts, 64 pints
105 quarts.....1 barrel (*bbl.*), dry measure, 7,056 cubic inches

Circular Measure

60 seconds (″).....1 minute (′)
60 minutes.....1 degree (°)
90 degrees.....1 quadrant (*quad.*)
4 quadrants.....1 circle

Nautical Measure

6 feet.....1 fathom (*fath.*)
100 fathoms.....1 cable's length (ordinary)
120 fathoms.....1 cable's length (United States Navy)
10 cable's lengths.....1 nautical mile
1 nautical mile.....1.1515 statute miles
60 nautical miles.....1 degree (*deg.* or °)

Conversion Table

Metric system into imperial system and imperial system into metric system. These values are very exact.

centimeter..... 0.3937 inch
meter.....39.37 inches (exactly)
square centimeter..... .1549997 square inch
square meter..... 1.195985 square yards
hectare..... 2.47104 acres
cubic meter..... 1.3079428 cubic yards
liter..... .264178 gallon
liter..... 1.05671 liquid quarts
liter..... .908102 dry quart
Hectoliter..... 2.83782 bushels
gram.....15.432356 grains
kilogram..... 2.204622341 pounds, avoirdupois
inch..... 2.540005 centimeters
yard..... .9144018 meter
square inch..... 6.451626 square centimeters
square yard..... .8361307 square meter
acre..... .404687 hectare
cubic yard..... .7645594 cubic meter
gallon..... 3.785332 liters
liquid quart..... .946333 liter
dry quart..... 1.101198 liters
bushel.....35.23833 liters
grain..... .064798918 gram
pound, avoirdupois..... .45359237 kilogram

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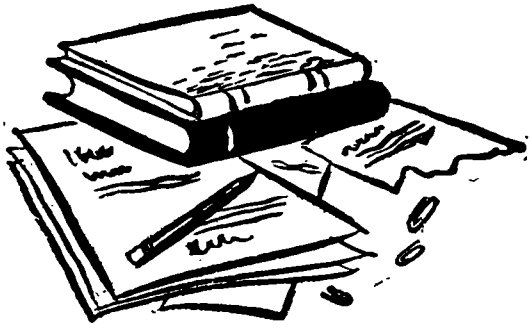

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